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SIMULATORS IN AVIATION MAINTENANCE TRAINING: A DELPHI STUDY

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This study gathered expert opinion on the use of simulators for training aviation maintenance technicians. Following the Delphi technique, three successive questionnaires were administered to 60 experts. The questionnaires asked what information an administrator needed to decide between simulators and real equipment for training at a Naval Aviation Maintenance Training Detachment. Included under information requirements were the areas of course content, economics, life-cycles, repairs, students and instructors. Suggested sources of information were considered. Additionally, the experts rated

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the feasibility, training effectiveness, and cost effectiveness of simulators for maintenance training for nine aircraft systems.

The questionnaire data were analyzed separately for Navy and Marine maintenance instructors (n = 26) and for all the other experts (professors, manufacturers, researchers, administrators) combined (n = 34). Although both groups agreed with each other in most areas, a few differences that may have significant practical applications were uncovered. The data should interest those associated with simulators used for training.

SUMMARY

The aim of this study was to gather expert opinion on the use of simulators for training technicians at Naval Aviation Maintenance Training Detachments (NAMTRADETs). The information collected was based on the expectation that the Navy will replace real equipment with simulators for training technicians in future years.

The opinions were collected with three successive questionnaires completed by 60 experts representing a variety of job categories—— Navy and Marine instructors, simulator manufacturers, university professors, researchers, and administrators. In the second and third questionnaires of the series, each expert was provided with the group's responses to the preceding questionnaire, and allowed to revise his previous opinion, a method of data collection known as the Delphi technique.

The questionnaires asked what information an administrator needed to decide between simulators and real equipment for training at a NAMTRADET. Also included was an estimate of how much effort would be required to obtain the needed information. Subsumed under information requirements were items on course content, economic considerations, life-cycle considerations, repair considerations, physical considerations, and considerations about instructors and students. Additionally, the experts judged the usefulness of various sources of information, both personnel and documents.

Also, on the assumption that an administrator had decided to procure a simulator, the questionnaires asked the experts to judge the importance of addressing various issues and to estimate the frequency with which each such issue had been addressed in the past.

Finally, the experts were asked to rate the feasibility, training effectiveness, and cost effectiveness of simulators for maintenance training for nine aircraft systems, separately for O-level and I-level maintenance.

The questionnaire data were analyzed separately for the Navy and Marine maintenance instructors (n = 26) and for all the other experts combined (n = 34). Although both groups agreed with each other in most areas, a few differences that may have significant practical implications were uncovered. For example, the instructor group disagreed among themselves concerning the feasibility, training effectiveness, and cost effectiveness of simulation for I-level maintenance training while the other experts were often in agreement and generally in favor of simulation for I-level training.

The results of the study should be of use to administrators, training analysts and planners, instructors, simulator manufacturers, and evaluators of maintenance simulators.

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I. INTRODUCTION

In the last few years about 30 simulators for aviation maintenance training have been introduced into Naval Aviation Maintenance Training Detachments (NAMTRADETs). With the expectation that many more simulators will be used at NAMTRADETs in future years, the Weapons Training Division, Code 413, of Logistics/Fleet Support of the Naval Air Systems Command tasked the Naval Air Development Center (NAVAIRDEVCEN), Code 6043, to report on the area of simulators for aviation maintenance training.

Although the literature on simulators in aviation is vast, almost all reports address the functions of air crews, not maintenance personnel. Moreover, the studies on simulators in aviation maintenance training that do exist are mostly descriptions of techniques or concepts still in the research and development stage or descriptions of field evaluations of simulators. Most of what is known, or at least believed, is grounded not on experimental data or theoretical foundations but on experience or best guesses based on a general knowledge of simulation and training.

Since the only extensive source of information is expert opinion, the decision was made to systematically collect and organize such expert opinion. The technique selected to obtain the experts' opinions was the Delphi Technique, a procedure devised by the Rand Corporation about thirty years ago.

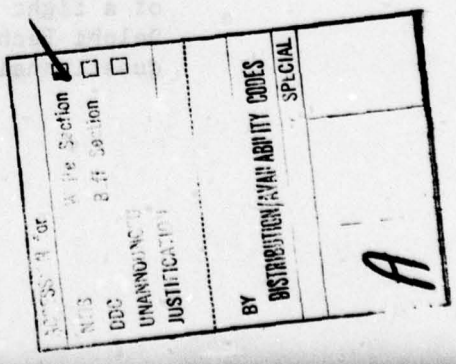
The Delphi Technique has been used in a variety of ways to obtain expert opinion on a variety of topics. For examples of the uses of the Delphi Technique, experimental evaluations of the Technique, as well as criticisms of the Technique, see Cooper, 1974; Dodge & Clark, 1977; Helmer, 1966, 1967; Linstone & Turoff, 1975; Quade & Boucher, 1968; Sackman, 1974.

The Delphi Technique, as employed in the present study, will be described in Section II, Data Collection Process.

II. DATA COLLECTION PROCESS

a. Delphi Technique

In the first questionnaire submitted to the experts, the Delphi Technique was described as follows:



The Delphi Technique is a method for obtaining and organizing the independent opinions of experts. The technique is based upon a series of questionnaires. The first questionnaire consists of a few general questions designed to evoke discussion of the selected topic by the experts. In their responses to the first questionnaire, the experts identify the areas of relevance and importance, describe their knowledge, provide examples and experiences to support their opinions, suggest problems, offer solutions. In short, in the first questionnaire the experts try to get at the essence of the topic under consideration. (Typically, the first questionnaire requires the most thought and time by the expert.)

The responses to the first questionnaire are analyzed, organized, and converted into individual items for the second questionnaire. Thus, by this procedure, the experts themselves, not the coordinator, determine the content of the second (and subsequent) questionnaires.

The format of the second questionnaire is like that of a typical questionnaire: the expert is presented with a series of items that he checks to indicate that he agrees or disagrees with a statement, or that an area is important or unimportant, or an approach is feasible or infeasible. In most cases, the response required is not simply a Yes-No, agree-disagree response, but a rating on a scale. For instance, the expert might be asked to check his preference on a 5-point scale varying from 1 (strongly agree) to 5 (strongly disagree).

The results of the second questionnaire are summarized by the coordinator and presented to the experts in the third questionnaire for further consideration. The aim of the Delphi Technique is to obtain a consensus of opinion on the topic under consideration.

Sometimes the Delphi Technique is continued through four or five or more questionnaires, with the goal of obtaining a consensus of opinion on every item. Because of a tight time schedule, the present application of the Delphi Technique will be limited to three successive questionnaires.

In many ways, the Delphi Technique accomplishes what one may accomplish by a well-run conference addressing a specific topic. The Delphi Technique, however, has certain advantages over a conference:

1. It gives each expert the opportunity to express his opinions without intimidation by other experts or by higher military or civilian authorities.

2. It allows the expert to express his hunches and half-thought-out opinions with impunity since responses are not attributed to any expert by name.

3. It provides the expert with the benefit of opinions from a variety of other experts with different orientations and biases.

4. It gives the expert the chance to leisurely examine the opinions of other experts before reacting.

b. Selection of Experts

To obtain opinions from experts who perceived simulators in different ways, experts with a variety of job categories were selected. Simulator manufacturers, university professors, administrators, researchers, and users of simulators (Navy and Marine aviation maintenance instructors) participated. From an initial pool of about 125 experts, invitations to participate were extended, by telephone or in person, to 62 experts. Sixty experts completed some or all of the three questionnaires (See Appendix A).

The composition of the experts is summarized in Table 1. As Table 1 indicates, there were 26 Navy and Marine aviation maintenance instructors. This group, the users of maintenance simualators, was purposely large in order to allow meaningful comparisons with the other experts. In the text that follows, the 26 instructors will be called the NAMTRADET group and the other 34 experts, collectively, will be termed the NON-NAMTRADET group.

The names and addresses of all participants are listed in Appendix B.

Table 1

Composition of experts participating in Delphi study of simulators in aviation maintenance training

Work Category	Institutional affiliation							
	Navy	Marines	Army	Air Force	Other Government	Industry	University	Total
Aviation maintenance instructor	23	3						26
Administrator	10		1	1	1	4	1	18
Researcher	3		4	1		5	1	14
Consultant						2		2
Total	36	3	5	2	1	11	2	60

c. Questionnaire One

Appendix C presents Questionnaire One, the material that accompanied the questionnaire, and the cover letter. The description of the Delphi Technique is omitted from Appendix C because it was given above. The material accompanying Questionnaire One oriented the expert to the Delphi Technique, described the training situation at a NAMTRADET, defined operational (real) equipment and simulators, and described maintenance levels in the Navy. The instructions to Questionnaire One pointed out that the study:

(1) is limited to maintenance training at NAMTRADETs,

(2) includes both O-level and I-level (but not depot level) maintenance training, and

(3) is limited to simulator systems that cost no more than $200,000.

Part of Questionnaire One consisted of four essay questions. Here is one of the four questions:

(1) General Comparisons.

If you were serving as an advisor to Naval administrators and were asked to list the advantages and disadvantages of simulators and the advantages and disadvantages of operational equipment for aviation maintenance training, how would you respond?

Another part of Questionnaire One, namely, Question V, required the expert to rate, on 5-point scales, the feasibility, training effectiveness, and cost effectiveness of simulation for nine aircraft systems (e.g., propulsion, electrical and instrument), separately for O-level and I-level maintenance. Question V was included because at least two Navy agencies had issued recommendations for simulating (or not simulating) aircraft systems for use in training, without documentation for their recommendations. Responses to Question V should provide a firmer basis for such recommendations.

The development of Questionnaire One, as well as subsequent questionnaires, was aided by inputs from members of NAVAIRDEVCEN, Code 604, and from aviation maintenance technicians assigned to NAS Willow Grove, Pennsylvania.

d. Questionnaire Two

Appendix D presents Questionnaire Two along with the cover letter. The sections on the Delphi Technique (given above) and on the background material (given in Appendix C) are omitted from Appendix D, although they were included with the material sent to the experts.

The development of Questionnaire Two was based on the responses to Questionnaire One, along with some additional material generated by the authors. Section I of Questionnaire Two assumed that an administrator faced the problem of deciding between a simulator and operational equipment to be used in a course at a NAMTRADET. In Section I the expert was asked to judge the utility of given information, and to judge the difficulty of obtaining such information. Section I also asked the expert to evaluate possible sources of information, both personnel and documents.

Section II of Questionnaire Two assumed that the administrator had decided to use a simulator, and asked the expert (a) to evaluate the issues to be considered to implement the simulator decision, and (b) to estimate how frequently these issues had been addressed in the past.

The second part of the development of Questionnaire Two consisted of summarizing the responses to Question V of Questionnaire One, namely, the material on feasibility, training effectiveness and cost effectiveness of simulators for O-level and I-level maintenance training. The procedure was to tally the number of experts selecting each of the five alternatives for each aircraft system for each category (e.g., feasibility), convert into percentages, and round each percentage to the nearest whole number. (See Appendix A for details on the number of questionnaires completed.)

The group's percentages were inserted in the tables which were then resubmitted to the experts as Section III of Questionnaire Two. For each item, each expert's own selection was circled in red to remind him of his previous selection (on Questionnaire One) while he examined the group's percentages to the same item. The expert was allowed to retain his previous selection or change to another alternative.

e. Questionnaire Three

Appendix E presents Questionnaire Three, along with its cover letter and a personnel data sheet.

The development of Questionnaire Three consisted of merely summarizing the results of Questionnaire Two and converting to percentages. (See Appendix A on the details of the number of experts contributing to the percentage calculations.)

A few new items, suggested by the experts when completing Questionnaire Two, were included in Questionnaire Three.

The tables on feasibility, cost effectivenesss, and training effectiveness, for O-level and I-level maintenance, initially presented in Questionnaire One and resubmitted in Questionnaire Two, were omitted from Questionnaire Three.

III. FINAL RESULTS

This section presents the tables of Questionnaire Three and the tables on simulators for O-level and I-level maintenance training from Questionnaire Two.

a. Groups

Although the questionnaires were presented to the experts as if the experts comprised a single group, in the analysis given

here, the total group was subdivided into two sub-groups: the NAMTRADET group, which consisted of the Navy and Marine maintenance instructors, and the NON-NAMTRADET group, which included all others. The NAMTRADET group consisted of 26 experts; the NON-NAMTRADET group consisted of 34 experts. For each group the data were analyzed and summarized separately, and then the two groups were compared.

b. Consensus

One aim of the Delphi Technique is to determine the items on which the experts are in agreement, i.e., the items on which there is a consensus of opinion. In Appendix F, the problem of defining consensus is discussed and a mathematical index of consensus is derived: if the interquartile range, namely, $P_{75} - P_{25}$, of a distribution of judgements to an item is less than 1.30, consensus exists; if the interquartile range is equal to or greater than 1.30, no consensus exists.

c. Data analyses

For each item of the tables,the 25th, 50th (the median), and 75th percentiles of the distribution of judgements were computed. Also, the interquartile range, namely, $P_{75} - P_{25}$, was computed to determine if a consensus of opinion existed.

For each item, the distribution of judgements of the NAMTRADET group was compared with the distribution of judgements of the NON-NAMTRADET group by the two-sample Kolmogorov-Smirnoff test (See Appendix F).

d. Reordering of items

For each section of each table to be presented, the items were listed according to two criteria. First, the items on which a consensus of opinion existed for either group were listed first. Second, within the list of consensus items, the order followed according to the value of the median (P_{50})--the lower the median, the earlier in the listing. When two or more categories of responses existed for an item (e.g., the categories "Need for information" and "Effort required to obtain information"), the ordering was based on the first category listed for the item. [The non-consensus items followed the consensus items, according to the value of the median.]

The principal purpose of reordering the items was to present, in a simple fashion, items on which the experts agreed, listed according to the importance attributed to the item.

e. Reading tables

Table 2 is an aid to reading Tables I, II, III, IV, and V that follow. The format and symbols illustrated in Table 2 were derived to summarize the results of the study without getting bogged down in numerical trivia.

Consensus, as discussed earlier (See Appendix F), is defined as a distribution of judgments that yields an interquartile range less than 1.30; that is, consensus exists when $(P_{75} - P_{25}) < 1.30$. In Table 2, an arrow represents consensus. A dashed arrow represents consensus for the NAMTRADET group; a solid arrow represents consensus for the NON-NAMTRADET group.

The scale on top of Table 2 represents the five alternatives, 1, 2, 3, 4, 5 and the vertical line on each side of a scale number represents the lower and upper limits of that number; thus the vertical line to the left of 1 represents the value 0.50 and the vertical line to the right of 1 represents 1.499. Similarly, the vertical line to the left of 2 designates 1.50 (or 1.499) and the vertical line to the right of 2 designates 2.499; etc..

An arrow points to the median (P_{50}) of the distribution of responses, referred to the scale just discussed. Thus, in item 20, for the Effort category, for the NON-NAMTRADET group the arrow designates $P_{50} = 2.3$, which falls in the alternative Slight Effort. For the same item and category, the arrow for the NAMTRADET group indicated $P_{50} = 1.4$, which falls in the alternative Little Effort.

When both the NAMTRADET group and the NON-NAMTRADET group demonstrated consensus, and their medians differed by 0.25 or less, the data for both groups were represented by a single double-headed arrow, as in item 1 of Table 2.

Nonconsensus in Table 2 is represented by a horizontal line and a dot. The line and dot refer to the scale discussed above. The left end of the horizontal line designates P_{25}, the right end designates P_{75}, and the dot designates P_{50}. A dashed line represents the NAMTRADET group; a solid line represents the NON-NAMTRADET group. In item 1 of Table 2, the dashed horizontal line indicates non-consensus for the NAMTRADET group, with distribution values of $P_{25} = 1.5$, $P_{50} = 2.3$, and $P_{75} = 3.1$.

Some items in Tables I - V referred both to simulators and to operational (real) equipment. In such cases, instead of repeating the item, the item was presented once but the expert made two judgments, one considering the item as referring to a simulator (S) and the other considering the item as referring to operational equipment (O). Item 20 of Table 2 illustrates such an item.

An asterisk (*) in a box indicates that the NAMTRADET and the NON-NAMTRADET distributions differed significantly (.05 level, two tailed, two-sample, Kolmogorov-Smirnoff test). The Effort category of item 20 indicates such a significant difference between the distributions of the two groups.

f. Results

The final results of the Delphi study are presented in Tables I through V.

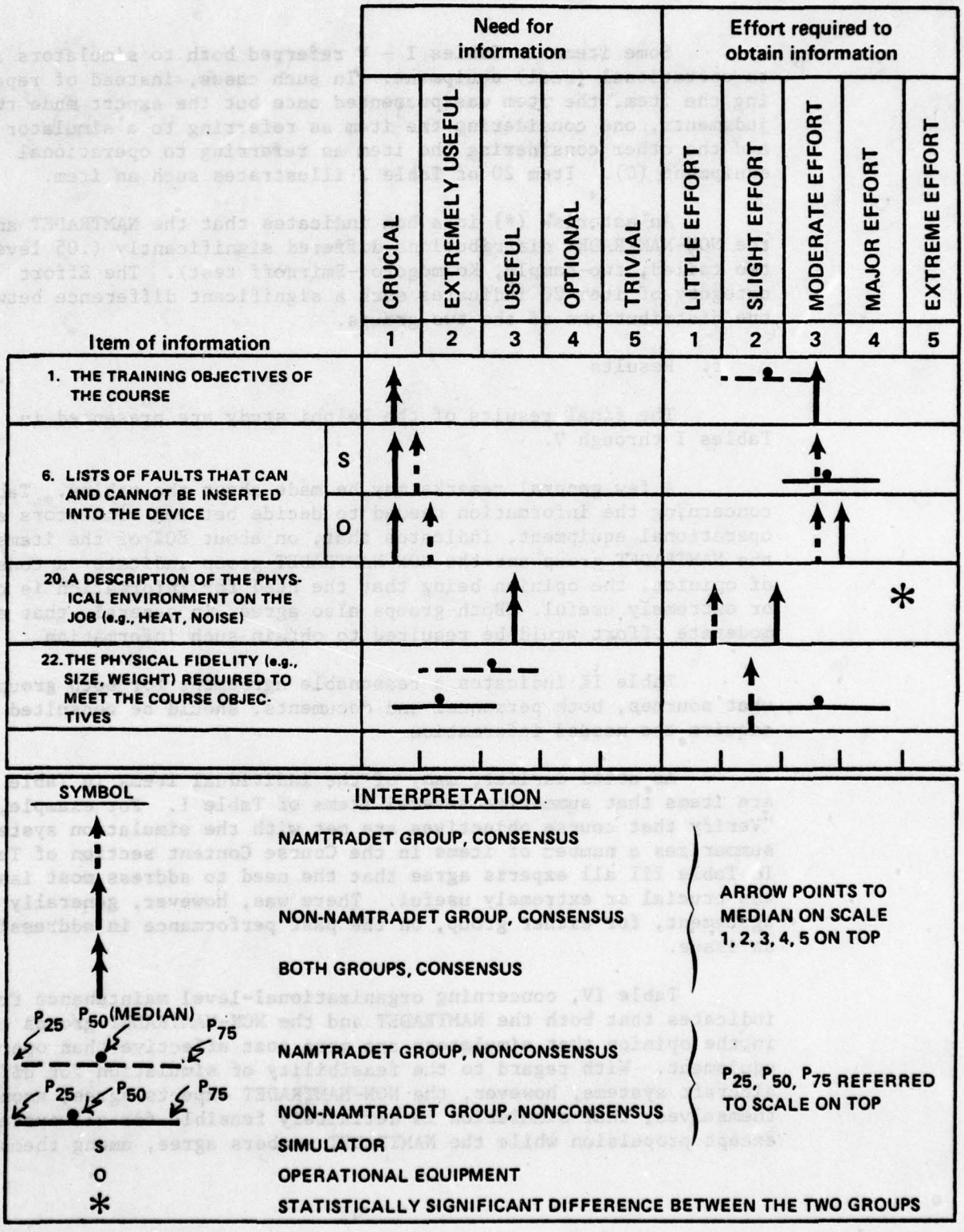
A few general remarks may be made about the tables. Table I, concerning the information needed to decide between simulators and operational equipment, indicates that, on about 80% of the items, both the NAMTRADET group and the NON-NAMTRADET group indicate a consensus of opinion, the opinion being that the need for information is crucial or extremely useful. Both groups also agree, in general, that a moderate effort would be required to obtain such information.

Table II indicates a reasonable agreement for both groups on what sources, both personnel and documents, should be consulted to acquire the needed information.

As noted earlier, many of the individual items in Table III are items that summarize several items of Table I. For example, "Verify that course objectives are met with the simulation system" summarizes a number of items in the Course Content section of Table I. In Table III all experts agree that the need to address most issues was crucial or extremely useful. There was, however, generally no agreement, for either group, on the past performance in addressing an issue.

Table IV, concerning organizational-level maintenance training, indicates that both the NAMTRADET and the NON-NAMTRADET groups concur in the opinion that simulators are more cost effective than operational equipment. With regard to the feasibility of simulation for different aircraft systems, however, the NON-NAMTRADET experts agree, among themselves, that simulation is definitely feasible for all systems except propulsion while the NAMTRADET members agree, among themselves,

Table 2
Illustration of table items and definitions for table symbols



that simulation is feasible for only four systems. For training, the NON-NAMTRADET group agree that simulation is more effective for most aircraft systems while the NAMTRADET experts fail to agree with each other on the training effectiveness for any system.

Table V, addressing intermediate-level maintenance, shows the greatest differences between the NAMTRADET and NON-NAMTRADET groups; in 15 of the 27 comparisons in this table, the two groups differed at a statistically significant level. Within the NAMTRADET group, a lack of consensus occurred on all but five occasions, and these five instances of consensus were votes against simulation. The NON-NAMTRADET experts agreed among themselves on 12 of the 27 occurrences, and all 12 agreements were in favor of simulation. In general, the NAMTRADET instructors hold a rather dim view of simulation for intermediate-level maintenance training while the NON-NAMTRADET experts feel, at least for some systems, that simulation is both feasible and cost effective.

g. Comments of experts

The experts were encouraged to provide comments when completing the questionnaires. Such comments, roughly classified in categories, are reproduced in Appendix G.

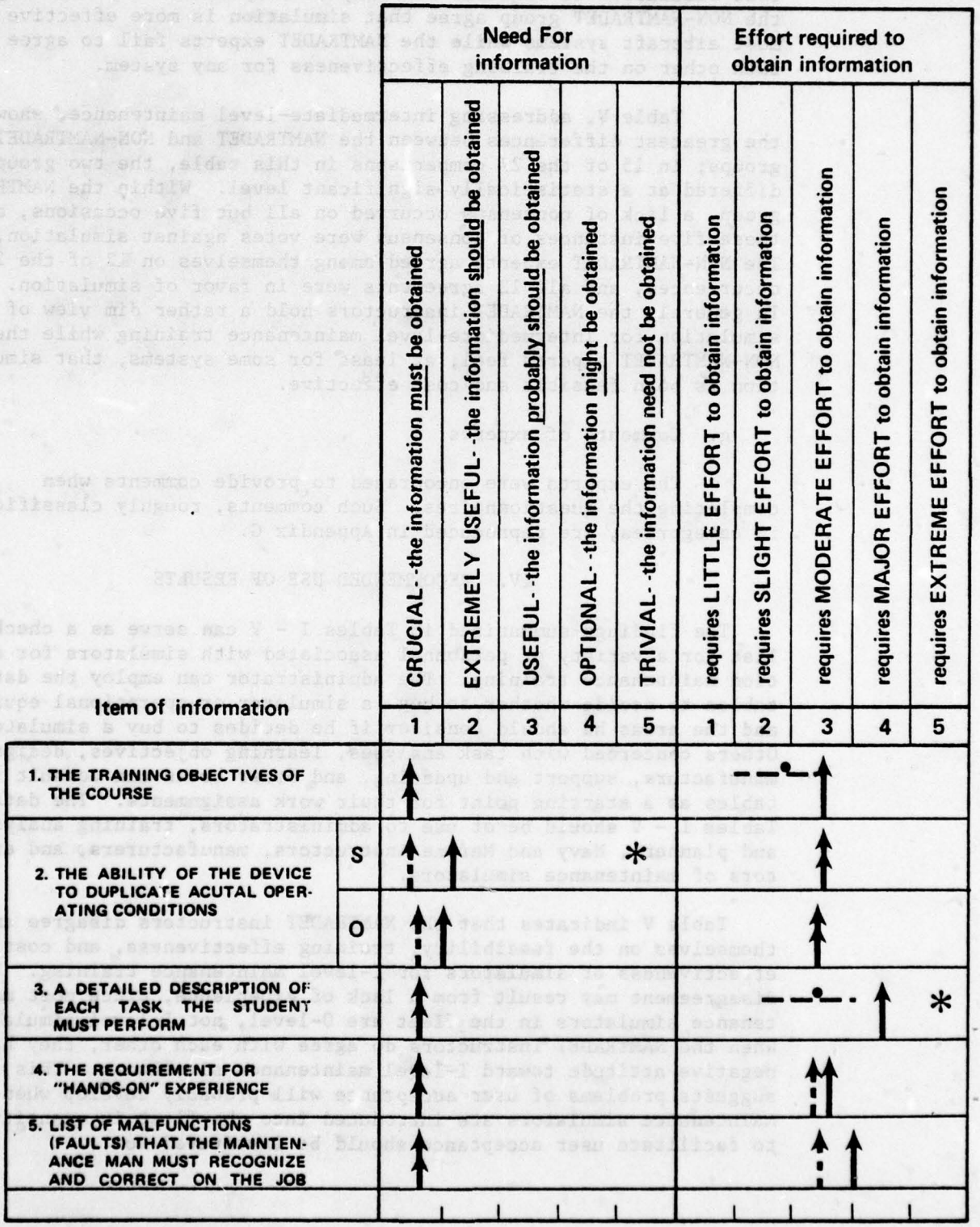
IV. RECOMMENDED USE OF RESULTS

The findings summarized in Tables I - V can serve as a checklist for a variety of personnel associated with simulators for aviation maintenance training. The administrator can employ the data tables to decide whether to buy a simulator or operational equipment, and the areas he should consider if he decides to buy a simulator. Others concerned with task analyses, learning objectives, design, manufacture, support and updating, and other areas can consult the tables as a starting point for their work assignments. The data of Tables I - V should be of use to administrators, training analysts and planners, Navy and Marine instructors, manufacturers, and evaluators of maintenance simulators.

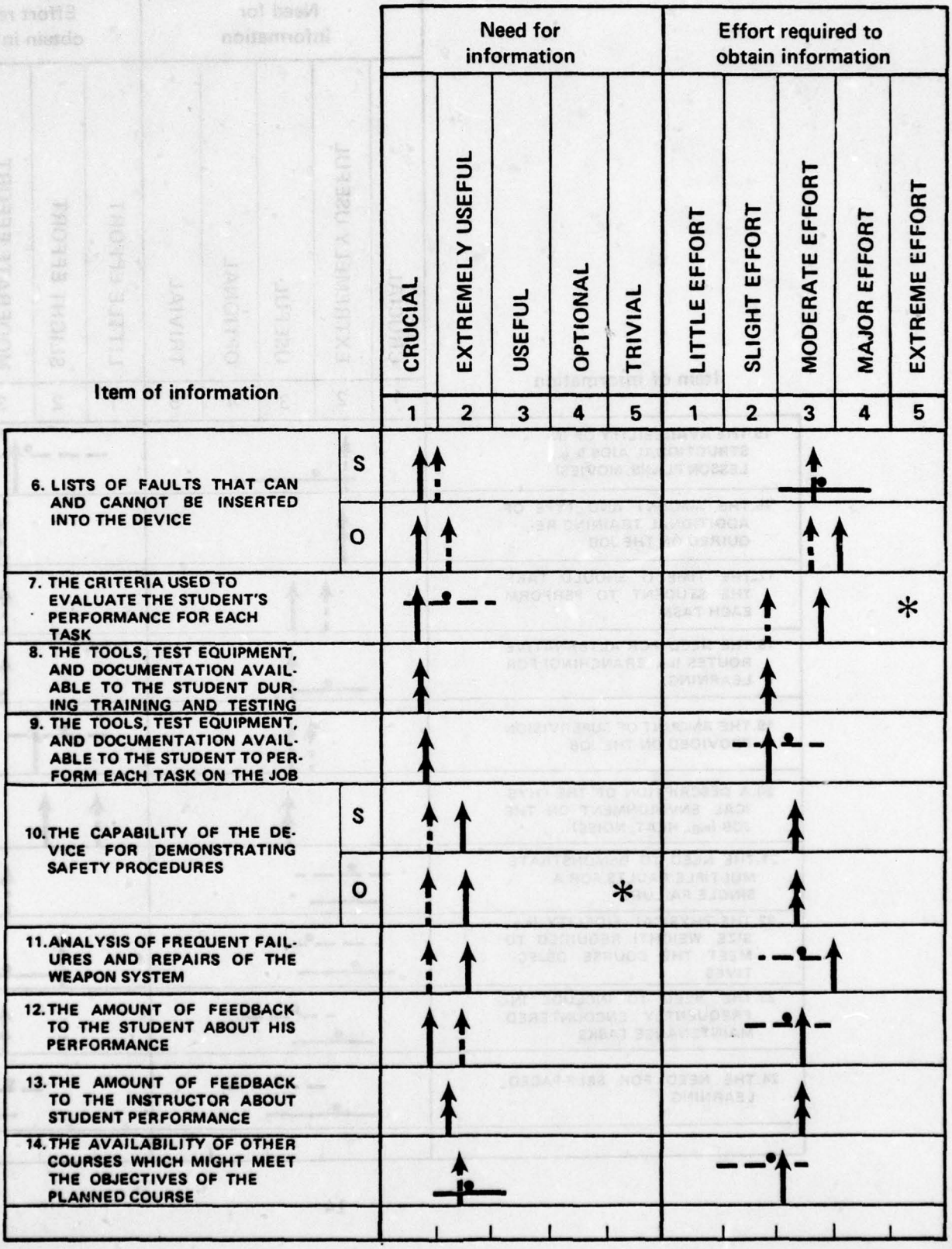
Table V indicates that the NAMTRADET instructors disagree among themselves on the feasibility, training effectiveness, and cost effectiveness of simulators for I-level maintenance training. This disagreement may result from a lack of experience, since most maintenance simulators in the fleet are O-level, not I-level simulators. When the NAMTRADET instructors do agree with each other, they have a negative attitude toward I-level maintenance simulators. This finding suggests problems of user acceptance will probably develop when I-level maintenance simulators are introduced into the fleet in quantity. Steps to facilitate user acceptance should be instituted now.

Table I. Information Required for Decision Making

COURSE CONTENT CONSIDERATIONS



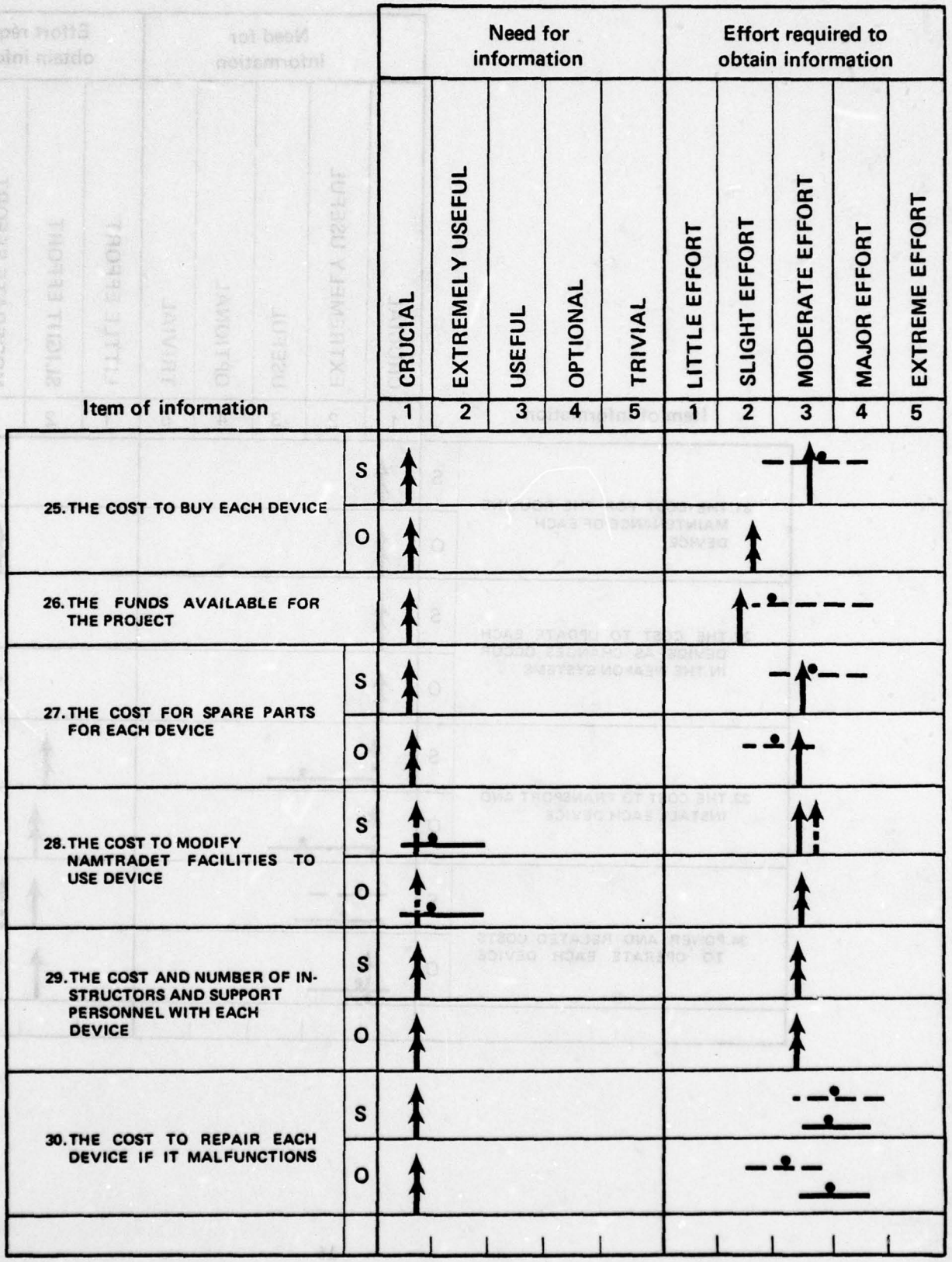
COURSE CONTENT CONSIDERATIONS



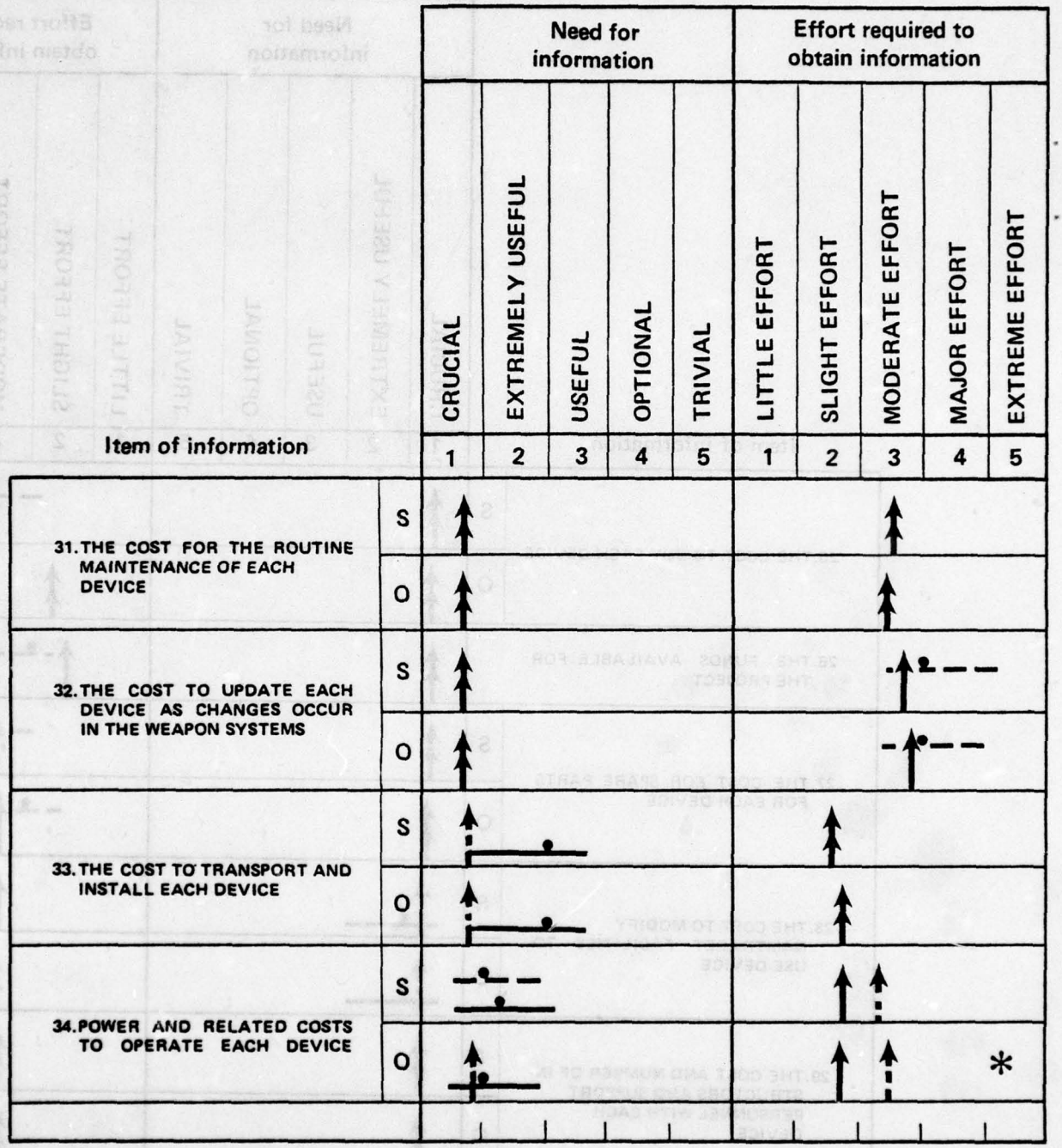
COURSE CONTENT CONSIDERATIONS

Item of information	Need for information					Effort required to obtain information				
	CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
	1	2	3	4	5	1	2	3	4	5
15. THE AVAILIBILITY OF INSTRUCTIONAL AIDS (e.g., LESSON PLANS, MOVIES)										
16. THE AMOUNT AND TYPE OF ADDITIONAL TRAINING REQUIRED ON THE JOB										
17. THE TIME IT SHOULD TAKE THE STUDENT TO PERFORM EACH TASK										
18. THE NEED FOR ALTERNATIVE ROUTES (i.e., BRANCHING) FOR LEARNING										
19. THE AMOUNT OF SUPERVISION PROVIDED ON THE JOB										
20. A DESCRIPTION OF THE PHYSICAL ENVIRONMENT ON THE JOB (e.g., HEAT, NOISE)										*
21. THE NEED TO DEMONSTRATE MULTIPLE FAULTS FOR A SINGLE FAILURE										
22. THE PHYSICAL FIDELITY (e.g., SIZE, WEIGHT) REQUIRED TO MEET THE COURSE OBJECTIVES										
23. THE NEED TO INCLUDE INFREQUENTLY ENCOUNTERED MAINTENANCE TASKS										
24. THE NEED FOR SELF-PACED LEARNING										

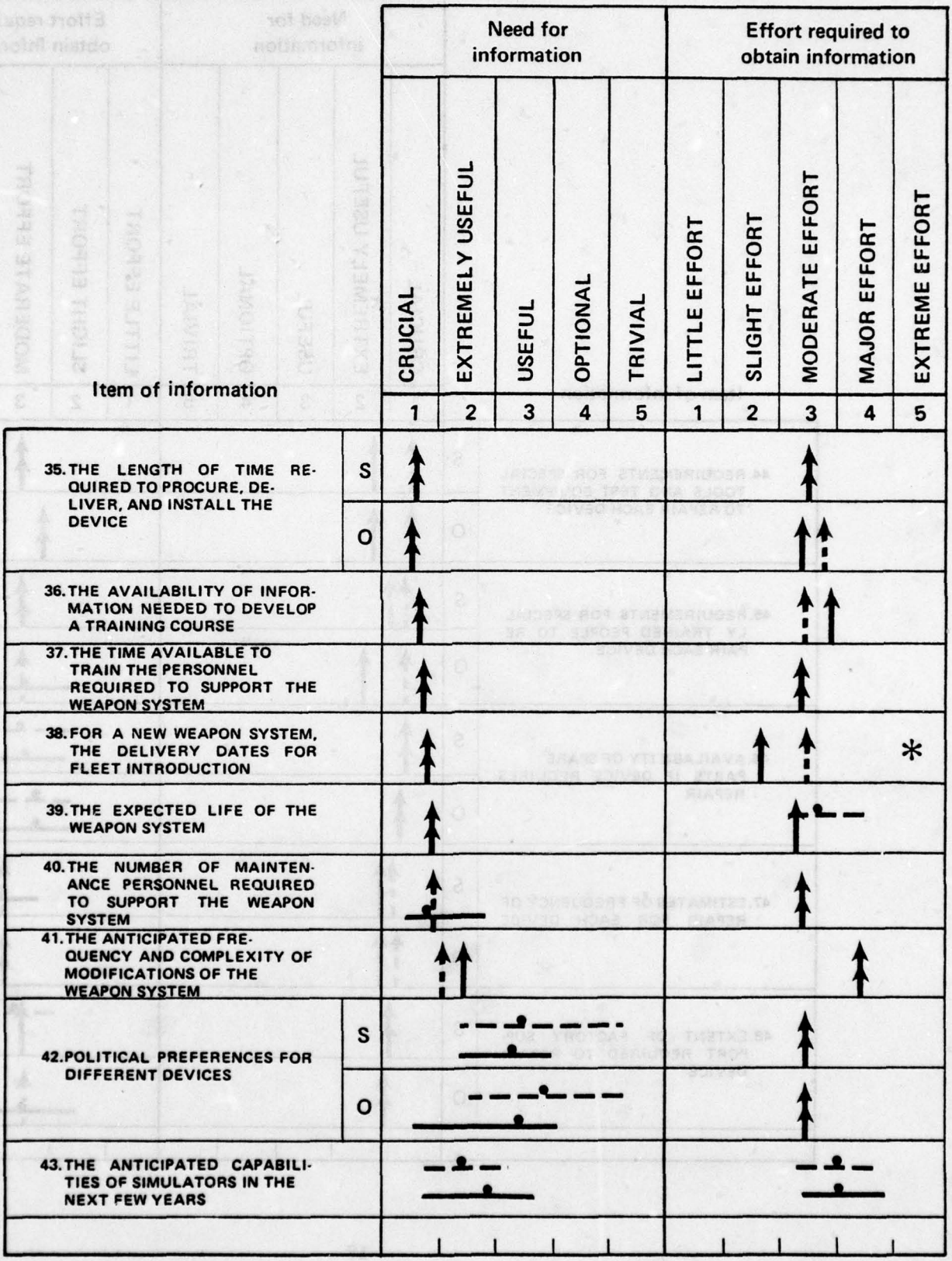
ECONOMIC CONSIDERATIONS



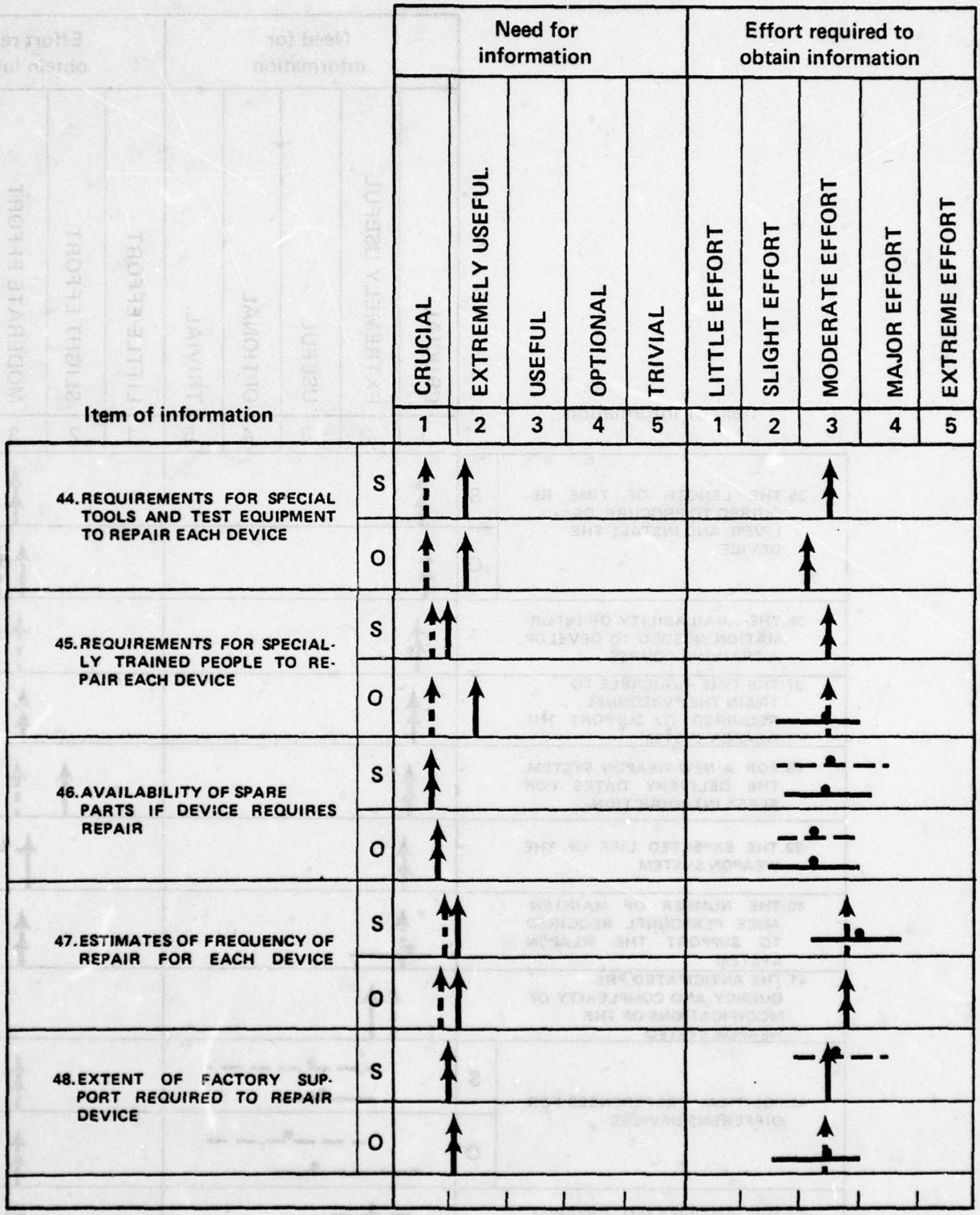
ECONOMIC CONSIDERATIONS



LIFE CYCLE CONSIDERATIONS



REPAIR CONSIDERATIONS



REPAIR CONSIDERATIONS

Item of information		Need for information					Effort required to obtain information				
		CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
		1	2	3	4	5	1	2	3	4	5
49. ESTIMATES OF AVERAGE TIME TO REPAIR EACH DEVICE	S		↑						↑		
	O		↑						↑		
50. THE ACCESSIBILITY OF COMPONENTS OF DEVICE REQUIRING REPAIR	S			●				↑			
	O			↑					↑		
51. THE LIKELIHOOD THAT THE STUDENTS MAY DAMAGE THE DEVICE	S			●					↑		
	O			●					↑		
52. REQUIREMENTS FOR SPECIAL DOCUMENTATION TO REPAIR EACH DEVICE	S			●					●		
	O			●					↑		

PHYSICAL CONSIDERATIONS

Item of information		Need for information					Effort required to obtain information				
		CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
		1	2	3	4	5	1	2	3	4	5
53. THE SCHEDULING FLEXIBILITY OF THE COURSE (i.e., WHAT WILL HAPPEN IF THE DEVICE IS INOPERATIVE?)	S										
	O										
54. THE NUMBER OF STUDENTS WHO COULD USE EACH DEVICE AT THE SAME TIME	S										
	O										
55. THE NUMBER OF STUDENTS TO BE TRAINED WITH THE DEVICE IN ONE YEAR	S										
	O										
56. THE DURABILITY OF EACH DEVICE UNDER FREQUENT USE	S										
	O										
57. THE ELECTRICAL OR OTHER POWER REQUIREMENTS FOR EACH DEVICE	S										
	O										

PHYSICAL CONSIDERATIONS

Item of information		Need for information					Effort required to obtain information				
		CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
		1	2	3	4	5	1	2	3	4	5
58. THE CLASS TIME THAT MIGHT BE SAVED WITH EACH DEVICE	S		↑						↑ ↑		*
	O		↑						↑ ↑		*
59. THE PERCENTAGE OF THE CLASS TIME THE DEVICE WILL BE USED	S		⊸						⊸		
	O		↑⊸						⊸		
60. THE DIMENSIONS AND WEIGHT OF THE DEVICE	S		↑					↑			
	O		↑					↑			
61. THE DURATION OF THE COURSE			↑						⊸		
62. THE PROBLEMS ASSOCIATED WITH MOVING AND STORING EACH DEVICE	S		↑ ↑						↑		
	O		↑ ↑						↑		
63. THE NUMBER OF SITES WHERE EACH DEVICE WILL BE USED	S		⊸						↑		
	O		⊸						↑		

CONSIDERATIONS ABOUT INSTRUCTORS AND STUDENTS

Item of information		Need for information					Effort required to obtain information				
		CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
		1	2	3	4	5	1	2	3	4	5
64. THE LIKELIHOOD THAT THE DEVICE MAY CAUSE INJURY TO THE STUDENT	S										
	O										
65. THE AMOUNT OF TRAINING OF INSTRUCTORS REQUIRED TO USE EACH DEVICE	S										
	O										
66. THE EXTENT OF INSTRUCTOR'S EXPERIENCE WORKING WITH MAINTENANCE OF THE SYSTEM											
67. THE EXTENT OF THE INSTRUCTOR'S EXPERIENCE TEACHING THE COURSE											
68. THE ATTITUDES OF STUDENTS ABOUT EACH DEVICE	S										
	O										
69. THE EDUCATIONAL BACKGROUND OF POTENTIAL STUDENTS											
70. THE ATTITUDES OF INSTRUCTORS ABOUT EACH DEVICE	S										
	O										

CONSIDERATIONS ABOUT INSTRUCTORS AND STUDENTS

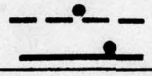
Item of information	Need for information					Effort required to obtain information				
	CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	LITTLE EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MAJOR EFFORT	EXTREME EFFORT
	1	2	3	4	5	1	2	3	4	5
71. THE MAINTENANCE EXPERIENCE OF POTENTIAL STUDENTS										

Table II. Sources of Information for Decision Making

PERSONNEL

Source of information	Need to consult				
	1 MANDATORY - must be consulted	2 PROBABLY VERY USEFUL - should be consulted	3 USEFUL - probably should be consulted	4 OPTIONAL - might be consulted	5 UNNECESSARY - need not be consulted
1. INSTRUCTORS OF THE COURSE					
2. MANUFACTURERS OF SIMULATORS					
3. RESEARCH PERSONNEL EXPERIENCED WITH SIMULATORS USED FOR TRAINING					
4. TRAINING ANALYSTS					
5. PERSONNEL DOING THE MAINTENANCE JOB IN THE FLEET					
6. COMPANIES WITH THE POTENTIAL FOR MANUFACTURING SIMULATORS					
7. INSTRUCTORS WHO ARE TEACHING WITH SIMULATORS					

PERSONNEL

Source of information	Need to consult				
	MANDATORY	PROBABLY VERY USEFUL	USEFUL	OPTIONAL	UNNECESSARY
	1	2	3	4	5
8. NAVY MANAGEMENT					
9. INSTRUCTORS TEACHING SIMILIAR COURSES					
10. NAVY SUPPLY SPECIALISTS					
11. NAVY PROCUREMENT SPECIALISTS					*
12. STUDENTS OF THE COURSE					
13. NAVY SCHOOL ADMINISTRATORS					
14. NAVY SAFETY SPECIALISTS					
15. AIRCRAFT MANUFACTURER					
16. GRADUATES OF THE COURSE					
17. MANUFACTURERS OF AIRCRAFT COMPONENTS					

DOCUMENTS

Source of information	Need to consult: MANDATORY (1)	PROBABLY VERY USEFUL (2)	USEFUL (3)	OPTIONAL	UNNECESSARY (5)
18. MAINTENANCE MANUALS FOR THE WEAPON SYSTEM					
19. MAINTENANCE PLAN(i.e., WRITTEN RECORD OF MAINTENANCE CONCEPT FOR SYSTEM AND EQUIPMENT, INCLUDING MAINTENANCE TASKS, LEVEL OF REPAIR ANALYSIS, AND SUPPORT AND EQUIPMENT)					
20. PERSONNEL AND TRAINING PLAN (i.e., WRITTEN RECORD OF PERSONNEL AND TRAINING REQUIRED TO OPERATE AND SUPPORT THE EQUIPMENT)					
21. TECHNICAL DATA PLAN (i.e., WRITTEN DESCRIPTION OF ALL INFORMATION AIDS NECESSARY TO OPERATE AND SUPPORT THE EQUIPMENT)					
22. RESEARCH AND EVALUATION REPORTS ON MAINTENANCE SIMULATORS					
23. FLIGHT MANUALS OF THE WEAPON SYSTEM					
24. FACILITIES REQUIREMENTS PLAN (i.e., WRITTEN RECORD OF SHIPBOARD, SHORE, OPERATIONAL, MAINTENANCE AND TRAINING FACILITIES)					
25. TRANSPORTATION AND HANDLING PLAN(i.e., WRITTEN REPORT OF PACKAGING, HANDLING, STORAGE, AND TRANSPORTATION REQUIREMENTS FOR EQUIPMENT)					*
26. RELEVANT GOVERNMENT INSTRUCTIONS					

Table III. Issues to be Addressed in Procuring Simulators

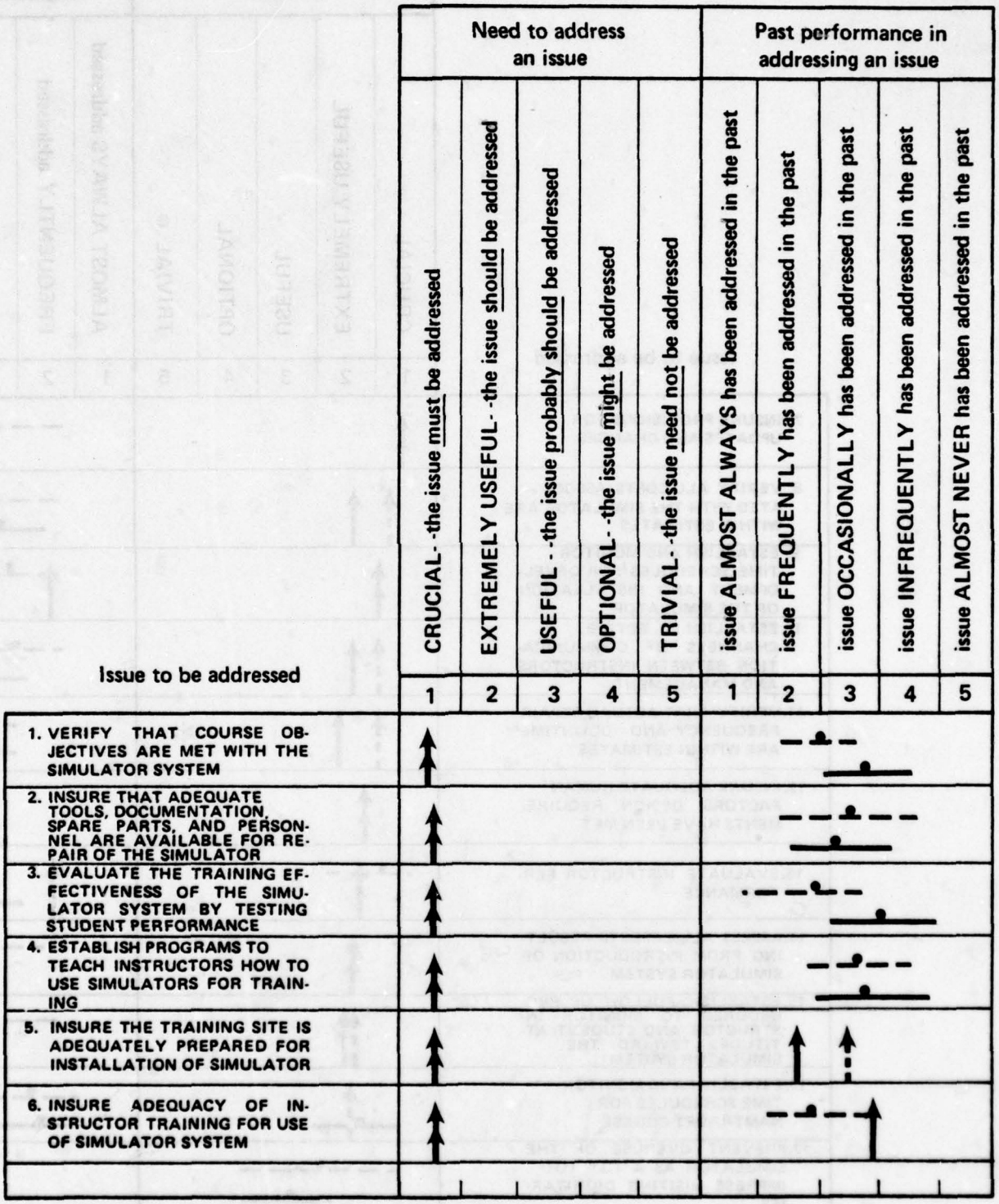


Table III

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	CRUCIAL	EXTREMELY USEFUL	USEFUL	OPTIONAL	TRIVIAL	ALMOST ALWAYS addressed	FREQUENTLY addressed	OCCASIONALLY addressed	INFREQUENTLY addressed	ALMOST NEVER addressed
	1	2	3	4	5	1	2	3	4	5
7. INSURE PROVISIONS FOR UPDATES AND CHANGES										
8. VERIFY ALL COSTS ASSOCIATED WITH THE SIMULATOR ARE WITHIN ESTIMATES										
9. ESTABLISH AND MONITOR TIME SCHEDULES FOR DEVELOPMENT AND INSTALLATION OF THE SIMULATOR										
10. ESTABLISH EFFECTIVE CHANNELS OF COMMUNICATION BETWEEN INSTRUCTORS AND MANAGEMENT										
11. VERIFY THAT ACTUAL REPAIR FREQUENCY AND "DOWNTIME" ARE WITHIN ESTIMATES				*						
12. INSURE ADEQUATE HUMAN FACTORS DESIGN REQUIREMENTS HAVE BEEN MET										
13. EVALUATE INSTRUCTOR PERFORMANCE									*	
14. ASSESS ALL EFFECTS RESULTING FROM INTRODUCTION OF SIMULATOR SYSTEM									*	
15. ESTABLISH FOLLOW UP PROCEDURES TO MONITOR INSTRUCTOR AND STUDENT ATTITUDES TOWARD THE SIMULATOR SYSTEM										
16. ESTABLISH AND MONITOR TIME SCHEDULES FOR NAMTRADET COURSE										
17. PREVENT OVERUSE OF THE SIMULATOR AS A TOY TO IMPRESS VISITING DIGNITARIES										

Table IV. Feasibility, Training Effectiveness, and Cost Effectiveness of Simulators for Organizational-Level Aircraft Maintenance Training at NAMTRADETS

Aircraft System	Feasibility: The simulation of most or all of this system is:					Training Effectiveness: Compared to operational equipment, simulators are:					Cost Effectiveness: Compared to operational equipment, simulators are:				
	Definitely feasible	Possibly feasible	Uncertain	Possibly infeasible	Definitely infeasible	Much more effective for training	Possibly more effective	Equally effective	Possibly less effective	Much less effective	Much more expensive	More expensive	Equally expensive	Less expensive	Much less expensive
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. ELECTRICAL & INSTRUMENT										*					
2. ANTISUBMARINE WARFARE					*										
3. COMMUNICATIONS AND NAVIGATION															
4. AUTOMATIC FLIGHT CONTROLS															
5. ARMAMENT/WEAPONS DELIVERY															
6. STRUCTURE, HYDRAULICS, & FLIGHT CONTROLS															
7. RECONNAISSANCE															
8. ENVIRONMENTAL/EGRESS															
9. PROPUSLION										*					

Table V. Feasibility, Training Effectiveness, and Cost Effectiveness of Simulators for Intermediate-Level Aircraft Maintenance Training at NAMTRADETS

Aircraft System	Feasibility: The simulation of most or all of this system is:					Training Effectiveness: Compared to operational equipment, simulators are:					Cost Effectiveness: Compared to operational equipment, simulators are:				
	Definitely feasible	Possibly feasible	Uncertain	Possibly infeasible	Definitely infeasible	Much more effective for training	Possibly more effective	Equally effective	Possibly less effective	Much less effective	Much more expensive	More expensive	Equally expensive	Less expensive	Much less expensive
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1. ELECTRICAL & INSTRUMENT					*					*					*
2. COMMUNICATIONS AND NAVIGATION					*					*					
3. ANTISUBMARINE WARFARE					*					*					
4. AUTOMATIC FLIGHT CONTROLS					*					*					
5. RECONNAISSANCE					*					*					
6. ARMAMENT/WEAPONS DELIVERY					*					*					
7. ENVIRONMENTAL/EGRESS															
8. STRUCTURE, HYDRAULICS, & FLIGHT CONTROLS					*										
9. PROPULSION					*										

V. REFERENCES

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APPENDIX A

Participation of experts in the Delphi study

A total of 62 experts were invited to participate in the Delphi study. The numbers of experts returning the questionnaires are summarized in Table A-1.

Table A-1

Number of experts returning questionnaires of Delphi study

Questionnaires returned	Numbers of experts
All three questionnaires	46
Only Questionnaires One and Two	3
Only Questionnaires One and Three	0
Only Questionnaires Two and Three	6
Only Questionnaire One	1
Only Questionnaire Two	2
Only Questionnaire Three	2
None	2

Note.--Each questionnaire was mailed to all 62 experts.

As discussed in the text, the responses of the experts to one questionnaire were summarized in percentages and resubmitted in a subsequent questionnaire. The percentages were computed on the final day specified for the return of a questionnaire. For example, 50 experts returned Questionnaire One, but two chose not to complete the O- and I-level tables and two others returned the questionnaire too late for inclusion in the computation of the percentages. Thus, the percentages given in the O- and I-level tables of Questionnaire Two are based on 46 experts. The preceding sentence must be qualified because not all of the 46 experts completed every one of the 54 selections for the O- and I-level tables.

In all computations, the percentages were based on the number of experts completing an item.

Table A-2

Number of experts used as a basis for computing percentages for questionnaire tables

Table Designation	Number of experts		
	Total group	NAMTRADET group	NON-NAMTRADET group
O- and I-level tables for Questionnaire Two	46	—	—
Tables for Questionnaire Three	52	—	—
Tables in final results	60	26	34

The same reasoning and rules were applied in the computation of the percentages for all tables, including those representing the final results. In addition, in computing the percentages for the final results (not given in this report), the most recent input from an expert was counted towards the final results. Thus, if an expert returned only Questionnaires One and Two, his data of Questionnaire Two were included in the final results.

APPENDIX B

Expert participants in Delphi study of simulators in aviation maintenance training

A. NAMTRADET instructors

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APPENDIX C

Questionnaire One and the material[1] provided with Questionnaire One

[1]The description of the Delphi Technique, which was included with Questionnaire One, is omitted. It is reproduced in the section on the Data Collection Process.

Dear _____

Thank you again for agreeing to serve as an expert in our study on aviation maintenance training simulators.

The enclosed material provides background information relevant to the study:

1. The Delphi Technique, the method to be used in this study, is described.
2. Definitions and descriptions are given for:
    a. The Navy training situation.
    b. Operational equipment and simulators.
    c. Maintenance programs in the Navy.

Following this background information is Questionnaire One, which you are asked to complete and return. A postage-free, addressed envelope is enclosed.

Although the study is specific to maintenance training in the Navy, it is likely that the results will be generalizable, at least to some extent, to other training situations. Thus, even if you are not associated with the Navy, you and your organization should profit from the study. A copy of the final report of the study will be sent to you.

I am enclosing my card. Contact me if necessary. If I am not available, ask for Joann Wright who is also working on this project.

One last request. The time schedule on this project is very tight. The Delphi Technique ordinarily takes a lot of time because the experts delay returning the questionnaires. Please return the enclosed questionnaire promptly, within a couple of days if at all possible. (Since you are going to spend time on it eventually, why not do it now?) If it's impossible to get to it immediately, please be sure to return it within ten days.

Sincerly,

ROBERT M. HERRICK

The opinions expressed or implied in the enclosed material are mine, not the Navy's. No remuneration will be provided to the participants of this study.

BACKGROUND MATERIAL

Training Situation

The training under consideration occurs at a Naval Aviation Maintenance Training Detachment (NAMTRADET), which is a technical school that supports the squadron at a Naval Air Station. Typically, a NAMTRADET includes several classrooms, each with chalkboards, slide projectors, and other common classroom aids. The student is provided with a variety of books, pamphlets, maintenance instruction manuals (MIMs), and other material to support his training. In recent years, the courses have included lists of instructional objectives (also called behavioral objectives, or specific behavioral objectives) so the student has a rather precise description of what he has to learn and what tasks he must learn to perform. Aircraft components are also on display or available for "hands-on" instruction in the classroom. An aircraft wing (costing perhaps a million dollars), or a radar system, or an ejection seat mounted in a section of an aircraft, or part of a computer system might be found in a typical classroom. Oscilloscopes, pressure gauges, and other test equipments are also available.

In Fiscal Year 1974, 1300 instructors at 49 NAMTRADETS presented 818 different courses in aircraft maintenance. Each of the 818 courses was taught several times for a total of 9,077 course presentations. There were 55,750 graduates of these courses in FY74.

Compared with conventional classroom training, the number of students attending a course is very low, usually 5 or 6.

The duration of a course at a NAMTRADET depends, naturally, upon the complexity and depth of training. Maintenance courses for the A-7 aircraft, for example, range from 8 hours to 480 hours. In FY74 the average course length was 111 hours.

The students attending the courses have varied backgrounds. Most are high school graduates. However, one student may be fresh from a technical school with approximately 9-17 weeks of technical training whereas another student may have had several years of Navy maintenance experience behind him.

Operational Equipment and Maintenance Training Simulators

The term operational equipment refers to real aircraft equipment or real test or other ground-support equipment. When operational equipment is used for training, the equipment may be in its normal condition or it may be modified somewhat; e.g., the cover of the equipment may be removed, the equipment may be partially disassembled, equipment that is normally adjacent to the equipment under study may be removed.

A maintenance training simulator is a training device that represents the components and the functioning of operational equipment. Although physical fidelity may not be a necessary requirement, simulators typically represent faithfully some or all of the components of the operational equipment. The student interacts with the simulator to acquire the knowledge and skills required for his maintenance tasks. Maintenance training simulators vary greatly in their complexity, training capabilities, and costs.

In the past few years, several NAMTRADETS have incorporated maintenance training simulators into their courses. The simulator most in use at NAMTRADETS is the EC II simulator of the Education Computer Corporation, which currently costs about $70,000. The EC II simulator comes in two sizes, a desk-type version for individual instruction and a large panel (about four foot high by ten foot wide) version for instructing several students simultaneously. Included in the EC II system are power supplies, a random access projector system, and a computer that can be programmed by a cassette tape. Each simulation model incorporates a display panel, a pictorial/schematic model of operational equipment, and means for "hands-on" interaction between the student (or the instructor) and the simulator.

Maintenance Levels

The Navy maintenance program distinguishes three levels of maintenance: organizational level (O level), intermediate level (I level), and depot level.

O-level maintenance is maintenance performed at an aircraft squadron on a day-to-day basis in support of its own operations. O-level maintenance includes equipment inspections, equipment servicing, equipment handling, corrective and preventive maintenance for equipment on board the aircraft. At the O-level, defective components are typically identified, removed, and replaced. The expression "remove and replace" is often used to characterize O-level maintenance, but, as indicated above, O-level maintenance includes other functions.

I-level maintenance is performed by shops in support of the aircraft squadron. Typically, most I-level maintenance is performed on components that have been removed from the aircraft. I-level maintenance includes repair, test, modification, calibration, and qualification testing of components.

Depot-level maintenance is maintenance for systems requiring major overhaul or a complete rebuild of parts, assemblies, subassemblies, or end items that is beyond the capability of I-level maintenance.

Each maintenance task is designated as O level, I level, or depot level, so each worker knows the limits of his task and knows when to pass on the maintenance task to the next higher maintenance level.

Here is an example of O-level and I-level maintenance tasks. The engine life recorder (ELR) of the AV-8A Harrier aircraft propulsion system measures the used life of the aircraft engine. Sensors in the engine measure the heat and time and convert that information to a count that is displayed on a digital counter.

At preflight and postflight inspections, the O-level technician tests the ELR for accuracy by measuring the count rate when a built-in test switch is in each of two test positions. If the ELR fails the tests, the technician replaces it and sends the defective ELR to the I-level maintenance shop. The O-level technician also logs the ELR count at preflight and postflight and performs scheduled checks.

The I-level technician troubleshoots the malfunctioning ELR, replaces the defective subassembly, and verifies his repair by performing a functional test. If the ELR cannot be repaired by the maintenance procedures approved for I-level maintenance, the technician ships the defective ELR to the depot maintenance shop. The I-level technician is also responsible for testing each new ELR that enters the supply system for his squadron.

QUESTIONNAIRE ONE

The aim of this study is to obtain expert opinion on the use of simulators versus the use of operational equipment in aviation maintenance training.

This study:

a) is limited to maintenance training at NAMTRADETS,

b) includes both O-level and I-level (but not depot level) maintenance training, and

c) is limited to simulator systems that cost no more than $200,000.

This first questionnaire consists of five questions. Questions I through IV are discussion questions. In answering these questions, present any ideas, opinions, facts, anecdotes, guesses, or hunches that you believe are relevant. If you can support a statement with facts or logic, do so; if not, include the statement anyhow. Consider yourself to be talking "off the record"; no statement you make will be attributed to you by name. In short, in answering Questions I through IV, err in the direction of giving too much rather than too little information. We can always ignore what we consider superfluous, but your opinion will not be heard if you fail to state it.

We are interested in <u>your personal opinions</u>, not the opinions of your supervisor or your colleagues or anyone else. So you will not influence or be influenced by others, <u>please do not discuss this or subsequent questionnaires with anyone.</u>

In responding to Questions I through IV indicate if (and where) you feel distinctions between O and I levels maintenance training are required.

To lessen your task on this first questionnaire, <u>don't concern yourself with writing well</u>. All that is necessary is that we are able to discern your meaning.

You may write or type your answers to Questions I through IV. However, if you prefer to dictate your answers, please do so. Send us a <u>cassette tape</u> of your remarks. If you want the tape (or a blank tape) returned, please indicate this on the tape. Also, give us your name at the beginning of the tape.

Question V is a specific question with instructions for answering.

In responding to questions I through V, feel free to add additional sheets if necessary and make any comments about the questions (general or specific). You are also encouraged to comment on any questions you feel we should have asked but have not.

There are many terms used in discussion of maintenance training and simulators. The following is a list of a few of the terms that are used. You may wish to consider some of these items when responding to the questions.

Roles of NAMTRADET training experts (instructors), aircraft manufacturer, simulator manufacturer and others.

Attitudes
Recurring costs
Fidelity
Versatility
"Hands-On"
Reliability
Maintenance of training equipment
Updating
Life span of curriculum
Procurement
Accessibility
Fault insertion
Safety
Power Requirements
Educational strategies
Individualized training
Transfer of training
Theory of instruction
Programming
Task/Skill analysis
Training Objectives (Specific Behavioral Objectives)
Class size
Instructor training
Administration of training
Evaluation
On the job training
Squadron/shop performance
Future state of the art
Standardization
Uniformity of training
Feedback
Measures of student behavior

NAME _____

I. General Comparisons.

If you were serving as an advisor to Naval administrators and were asked to list the advantages and disadvantages of simulators and the advantages and disadvantages of operational equipment for aviation maintenance training, how would you respond?

NAME _____

II. Factors in Decision Making.

This question deals with <u>how</u> the decision should be made to use operational equipment or simulators for maintenance training. What information should the decision-maker have available to him? What sources of information are likely to be most valuable? What factors are most critical in the decision process? Which are least critical?

NAME _____

III. Specification for Simulator System.

An administrator decides a simulator rather than operational equipment should be used for maintenance training in a particular NAMTRADET course. What items should be included in the contract for the simulator system? What personnel should contribute to the specification for the simulator system?

NAME _____

IV. Introduction of Simulators.

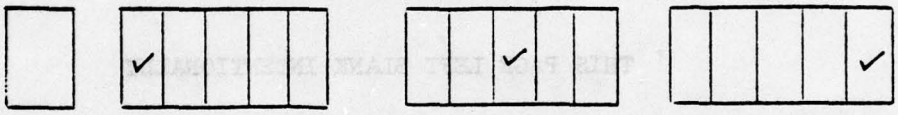
When simulaters are introduced (or in use) at NAMTRADETS there are sometime obstacles which hinder their acceptance and use. What are some problems which might hinder acceptance and/or use? What actions can be taken at your level to reduce these problems? What actions can be taken by higher authority?

V. The following question asks you to rate the feasibility, the training effectiveness, and the cost of simulation for training for each of ten aircraft systems. Each of the ten systems, which are briefly described on the following page, includes a variety of equipment. You may have different judgements for different equipments within one system. If so, your rating should apply to most of the equipment within a system.

Two answer sheets are provided. One, as marked, applies to your ratings for organizational-level maintenance training; the other applies to intermediate-level maintenance training.

The first column of each answer sheet is labelled "totally ignorant of this system". Check this column only if you have no knowledge at all of the system. You do not have to be an expert in the particular system to provide ratings. Your general knowledge of a system is sufficient for you to participate.

Here is an example of ratings for a system:



These ratings indicate that simulation is definitely feasible (for most or all of the system), that simulation is as effective as operational equipment for training, and that simulation is much less expensive than operational equipment.

BRIEF DESCRIPTIONS OF AIRCRAFT MAINTENANCE SYSTEMS

Structure, Hydraulics and Flight Controls Systems - includes for example: airframe structure components, corrosion control, hydraulic power supply and distribution systems, alighting and launching gear, wing and fin fold systems, primary and secondary flight control systems, empennage.

Propulsion Systems - includes for example: engine maintenance, quick engine change, assembly and buildup, removal/installation, aircraft fuel storage and transfer, fuel system operation and maintenance.

Electrical and Instrument Systems - includes for example: drive generator, electrical power supply and distribution, instrument indicating systems, lighting, and electrical circuits for following systems: engine and related system, hydraulic, environmental, life support, armament.

Environmental Control and Egress Systems - includes for example: cabin air conditioning, cabin air pressurization, crew egress component/subsystems, oxygen system.

Armament/Weapons Delivery System - includes for example: guns, mounts, weapon direction equipment, launcher, pods, bomb racks and other mechanical or electro-mechanical equipment for weapons delivery function.

Communications and Navigation Systems - includes for example: intercom, radio system(s), data link, radar, radio, direction finding set, doppler compass.

Automatic Flight Controls - includes for example: automatic pilot, flight displays, mechanical and electrical parts for signal transmission and application of power, reference sensors, air data computer.

Reconnaissance Equipment - equipment necessary to reconnaissance mission. Includes for example: photographic and electronics, infared and other sensors, search receivers, recorders, warning devices, magazines and data link.

Anti-Submarine Warfare - equipment peculiar to the antisubmarine warfare. mission. Includes for example: acoustic and nonacoustic sensor systems, computer, displays.

ORGANIZATIONAL LEVEL

(Refer to earlier descriptions for distinctions between O-level and I-level maintenance)

	Totally ignorant of this system	The simulation of most or all of this system is:					Compared to operational equipment simulators are:									
		1. Definitely feasible	2. Possibly feasible	3. Uncertain	4. Possibly infeasible	5. Definitely infeasible	1. Much more effective for training	2. Possibly more effective	3. Equally effective	4. Possibly less effective	5. Much less effective	1. Much more expensive	2. More expensive	3. Equally expensive	4. Less expensive	5. Much less expensive
Structure, Hydraulics, & Flight Controls																
Propulsion																
Electrical & Instrument																
Environmental/Egress																
Armament/Weapons Delivery																
Communications and Navigation																
Automatic Flight Controls																
Reconnaissance																
Antisubmarine Warfare																

INTERMEDIATE LEVEL

(Refer to earlier descriptions for distinctions between O-level and I-level maintenance)

	Totally ignorant of this system	The simulation of most or all of this system is:					Compared to operational equipment simulators are:									
		1. Definitely feasible	2. Possibly feasible	3. Uncertain	4. Possibly infeasible	5. Definitely infeasible	1. Much more effective for training	2. Possibly more effective	3. Equally effective	4. Possibly less effective	5. Much less effective	1. Much more expensive	2. More expensive	3. Equally expensive	4. Less expensive	5. Much less expensive
Structure, Hydraulics, & Flight Controls																
Propulsion																
Electrical & Instrument																
Environmental/Egress																
Armament/Weapons Delivery																
Communications and Navigation																
Automatic Flight Controls																
Reconnaissance																
Antisubmarine Warfare																

APPENDIX D

Questionnaire Two and the material[1] provided with Questionnaire Two

[1] The sections on the Delphi Technique (given in the text of this report) and on the background material (given in Appendix B) are omitted from this appendix.

Dear _____

Thank you for completing Questionnaire One in our Delphi Study of simulators and operational equipment in aviation maintenance training.

We encountered a few minor problems with Questionnaire One because some of the experts failed to follow directions. For example, when completing the table of Questionnaire One, one expert decided that the system "Structures, Hydraulics, & Flight Controls" was too broad so he split it into two systems and then responded. Since his responses could not be integrated with the responses of the other experts, his responses to this item had to be discarded. Another problem was that a few of the experts failed to complete all items.

In completing Questionnaire Two, which is enclosed, please follow directions carefully. If you have any comments about any of the items of Questionnaire Two, first respond to the item, then give your comment, either in the margin or on the back of the sheet.

Please complete Questionnaire Two promptly, within a couple of days if possible. Your cooperation and quick response will be greatly appreciated.

Sincerely,

ROBERT M. HERRICK

The blue sheets describing the background material and the Delphi Technique, which were included with Questionnaire One, are included again.

Introduction to Questionnaire Two

The aim of this study is to obtain expert opinion on the use of simulators versus operational equipment in aviation maintenance training.

This study:

a) is limited to maintenance training at NAMTRADETS,

b) includes both O-level and I-level (but not depot level) maintenance training, and

c) is limited to simulation systems that cost no more than $200,000.

Questionnaire Two consists of three sections. In writing Section I we imagined a naval administrator confronted with a choice between simulators and operational equipment for a NAMTRADET course. We ask, in this section, what information is needed to aid the administrator, and how difficult is it to obtain such information. Also, in Section I, we ask about possible sources of information, both personnel and relevant documents.

In Section II we assume that the administrator has decided to use a simulator rather than operational equipment. And we ask: What issues should the administrator consider to implement his decision? And, how frequently have these issues been considered in the past?

In Sections I and II no distinctions are made between O-level and I-level maintenance training. In giving your opinions in these two sections consider each item to apply to both O-level and I-level training.

Section III presents the results of Question V of Questionnaire One and gives you the opportunity to retain or revise your opinions.

Specific Instructions for Completing Table I

Table I concerns gathering and evaluating information to help decide between simulators and operational equipment.

An illustration will indicate the procedure you are to follow in completing Table I. Reproduced below are two items of Table I.

Item of Information		Need for information					Effort required to obtain information				
		1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
23. The funds available for the project		X						X			
24. The cost to buy each device	S	X								X	
	O	X						X			

[The column headings (e.g., 1. CRUCIAL--the information must be obtained) have been omitted here. Refer to the first page of Table I for the complete headings.]

In the above illustration the expert decided that item 23. "The funds available for the project" is information that must be obtained. He therefore placed an X in the box 1. CRUCIAL--the information must be obtained. For item 23., he also decided that it would require slight effort to obtain such information. Therefore, he marked X under 2., requires SLIGHT EFFORT to obtain information.

In each row of Table I you are to follow the same procedure, namely, mark an X for one of the five alternatives under the category "Need for information," and mark an X for one of the five alternatives under the category "Effort required to obtain information."

In many of the items we use the word device in a special way. By device we mean either a simulator or operational equipment. Thus, in item 24. above, "The cost to buy each device" means the cost to buy a simulator or the cost to buy operational equipment. Instead of listing two items separately, one for simulators and one for operational equipment, we list only one item. However, we split the section for your responses into two rows, one marked "S" for simulators and one marked "O" for operational equipment. Fill in each row as described above. In the example given above, in the category "Need for information," the expert marked 1. CRUCIAL for both simulators (the row marked "S") and for operational equipment (the row marked "O"). In the other category, "Effort required to obtain information," the expert marked 4. MAJOR EFFORT for simulators and 2. SLIGHT EFFORT for operational equipment.

Comments about items may be written in the margins or on the back of the pages.

In the blank rows at the end of Table I you may add new items.

NAME_____

Section I. Gathering Information to Help the Decision Maker Decide between Simulators and Operational Equipment.

Table I. Information Required for Decision Making

Item of Information	Need for information					Effort required to obtain information				
	1. CRUCIAL--the information must be obtained	2. EXTREMELY USEFUL--the information should be obtained	3. USEFUL--the information probably should be obtained	4. OPTIONAL--the information might be obtained	5. TRIVIAL--the information need not be obtained	1. requires LITTLE EFFORT to obtain information	2. requires SLIGHT EFFORT to obtain information	3. requires MODERATE EFFORT to obtain information	4. requires MAJOR EFFORT to obtain information	5. requires EXTREME EFFORT to obtain information
COURSE CONTENT CONSIDERATIONS										
1. A detailed description of each task the student must perform										
2. The time it should take the student to perform each task										
3. The tools, test equipment, and documentation available to the student during training and testing										
4. The criteria used to evaluate the student's performance for each task										
5. The training objectives of the course										
6. The amount of supervision provided on the job										

Table I (continued)

Item of information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
7. A description of the physical environment on the job (e.g., heat, noise)											
8. The physical fidelity (e.g., size, weight) required to meet the course objectives											
9. The availability of other courses which might meet the objectives of the planned course											
10. The availability of instructional aids (e.g., lesson plans, movies)											
11. The amount of feedback to the instructor about student performance											
12. The amount of feedback to the student about his performance											
13. Analysis of frequent failures and repairs of the weapon system											
14. The tools, test equipment, and documentation available to the student to perform each task on the job											
15. List of malfunctions (faults) that the maintenance man must recognize and correct on the job											
16. Lists of faults that can and cannot be inserted into the device	S										
	O										
17. The need to demonstrate multiple faults for a single failure											
18. The need to include infrequently encountered maintenance tasks											
19. The requirement for "hands-on" experience											
20. The amount and type of additional training required on the job											

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
21. The need for self-paced learning											
22. The need for alternative routes (i.e., branching) for learning											
ECONOMIC CONSIDERATIONS											
23. The funds available for the project											
24. The cost to buy each device	S										
	O										
25. The cost for spare parts for each device	S										
	O										
26. The cost to transport and install each device	S										
	O										
27. The cost to modify NAMTRADET facilities to use device	S										
	O										
28. Power and related costs to operate each device	S										
	O										
29. The cost for the routine maintenance of each device	S										
	O										
30. The cost to repair each device if it malfunctions	S										
	O										
31. The cost to update each device as changes occur in the weapon system	S										
	O										
32. The cost and number of instructors and support personnel with each device	S										
	O										
LIFE CYCLE CONSIDERATIONS											
33. Political preferences for different devices	S										
	O										

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
34. The expected life of the weapon system											
35. For a new weapon system, the delivery dates for fleet introduction											
36. The number of maintenance personnel required to support the weapon system											
37. The time available to train the personnel required to support the weapon system											
38. The length of time required to procure, deliver, and install the device	S										
	O										
39. The availability of information needed to develop a training course											
40. The anticipated frequency and complexity of modifications of the weapon system											
41. The anticipated capabilities of simulators in the next few years											
REPAIR CONSIDERATIONS											
42. Estimates of frequency of repair for each device	S										
	O										
43. Estimates of average time to repair each device	S										
	O										
44. Requirements for special tools and test equipment to repair each device	S										
	O										
45. Requirements for specially trained people to repair each device	S										
	O										

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
46. Requirements for special documentation to repair each device	S										
	0										
47. Availability of spare parts if device requires repair	S										
	0										
48. Extent of factory support required to repair device	S										
	0										
49. The accessibility of components of device requiring repair	S										
	0										
PHYSICAL CONSIDERATIONS											
50. The dimensions and weight of the device	S										
	0										
51. The electrical or other power requirements for each device	S										
	0										
52. The problems associated with moving and storing each device	S										
	0										
53. The durability of each device under frequent use	S										
	0										
54. The number of sites where each device will be used	S										
	0										
55. The number of students who could use each device at the same time	S										
	0										
56. The number of students to be trained with the device in one year	S										
	0										
57. The duration of the course											
58. The percentage of the class time the device will be used	S										
	0										

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
59. The class time that might be saved with each device	S										
	O										
60. The scheduling flexibility of the course (i.e., what will happen if the device is inoperative?)	S										
	O										
CONSIDERATIONS ABOUT INSTRUCTORS AND STUDENTS											
61. The extent of instructor's experience working with maintenance of the system											
62. The extent of the instructor's experience teaching the course											
63. The attitudes of instructors about each device	S										
	O										
64. The amount of training of instructors required to use each device	S										
	O										
65. The educational background of potential students											
66. The maintenance experience of potential students											
67. The attitudes of students about each device	S										
	O										
Add New Items Here											

Specific Instructions for Completing Table II

Table II lists possible sources to be consulted when gathering information to help decide between simulators and operational equipment.

An illustration will indicate the procedure you are to follow in completing Table II. Reproduced below are two items of Table II.

Source of Information	Need to consult 1.	2.	3.	4.	5.
1. Instructors of the course	X				
2. Instructors teaching similiar courses		X			

[The column headings (e.g., 1. MANDATORY--must be consulted) have been omitted here. Refer to the first page of Table II for the complete headings.]

In the above illustration the expert decided that item 1. "Instructors of the course" must be consulted. He therefore placed an X in the box 1. MANDATORY--must be consulted. In item 2. "Instructors teaching similiar courses," the expert decided that it would probably be very useful to consult such a source. He therefore placed an X in box 2. PROBABLY VERY USEFUL--should be consulted. In each row of Table II, you are to follow the same procedure, namely, mark an X for one of the five alternatives under the category "Need to consult."

[Note: In Table II we are concerned with the need to consult each listed source to help decide between simulators and operational equipment. Such sources should also prove useful after the decision has been made to buy a simulator or operational equipment.]

Comments about the items may be written in the margins or on the back of the pages.

In the blank rows at the end of Table II you may add other sources of information.

NAME_____

Table II. Sources of Information for Decision Making

Source of Information	Need to consult				
	1. MANDATORY--must be consulted	2. PROBABLY VERY USEFUL--should be consulted	3. USEFUL--probably should be consulted	4. OPTIONAL--might be consulted	5. UNNECESSARY--need not be consulted
PERSONNEL					
1. Instructors of the course					
2. Instructors teaching similiar courses					
3. Instructors who are teaching with simulators					
4. Training analysts					
5. Personnel doing the maintenance job in the fleet					
6. Graduates of the course					
7. Students of the course					
8. Aircraft manufacturer					
9. Manufacturers of aircraft components					

Table II (continued)

Source of Information	Need to consult				
	1. MANDATORY	2. PROBABLY VERY USEFUL	3. USEFUL	4. OPTIONAL	5. UNNECESSARY
10. Navy supply specialists					
11. Navy procurement specialists					
12. Navy safety specialists					
13. Manufacturers of simulators					
14. Navy school administrators					
15. Navy management					
DOCUMENTS					
16. Maintenance manuals for the weapon system					
17. Flight manuals of the weapon system					
18. Maintenance Plan (i.e., written record of maintenance concept for system and equipment, including maintenance tasks, level of repair analysis, and support and test equipment requirements)					
19. Personnel and Training Plan (i.e., written record of personnel and training required to operate and support the equipment)					
20. Technical Data Plan(i.e., written description of all information aids necessary to operate and support the equipment)					
21. Facilities Requirements Plan (i.e., written record of shipboard, shore, operational, maintenance, and training facilities)					
22. Transportation and Handling Plan (i.e., written record of packaging, handling, storage, and transportation requirements for equipment)					

Table II (continued)

Source of Information	Need to consult				
	1. MANDATORY	2. PROBABLY VERY USEFUL	3. USEFUL	4. OPTIONAL	5. UNNECESSARY
23. Relevant government instructions					
24. Research and evaluation reports on maintenance simulators					
Add new items here					

Specific Instructions for Completing Table III

In this section we assume that the administrator has considered all the relevant information and decided to use simulators rather than operational equipment. Table III concerns the administrator's role in implementing his decision.

Most of the items in Tables I and II, which were applicable to the decision process, are applicable also to the implementation process--the process of procuring, installing, and using a simulator system. Rather than repeat the items of Tables I and II in Table III we have chosen to list items that summarize much of the material of Tables I and II. In addition to the summary items, Table III includes material not considered in Tables I and II. Also, Table III asks you to judge how frequently the issues have been considered in past simulation systems.

An illustration will indicate the procedure you are to follow in completing Table III. Reproduced below is one item of Table III.

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
1. Verify that course objectives are met with the simulator system	X								X	

[The column headings (e.g., 1. CRUCIAL--the issue must be addressed) have been omitted here. Refer to the first page of Table III for the complete headings.]

In the above illustration the expert decided that item 1. "Verify that course objectives are met with the simulator system" is an issue that must be addressed in procuring simulators. He therefore placed an X in the box 1. CRUCIAL-- the issue must be addressed. For the same item, he also decided that the issue had been infrequently considered in past simulation systems. Therefore, he placed an X in alternative 4. issue INFREQUENTLY has been addressed in the past.

In each row of Table III you are to follow the same procedure, namely, mark an X for one of the five alternatives under the category "Need to address an issue," and mark an X for one of the five alternatives under the category "Past performance in addressing an issue."

Comments about the items may be written in the margins or on the back of the pages.

In the blank row at the end of Table III you may add new items.

NAME_____

Section II. The Implementation of a Decision to Use Simulators.

Table III. Issues to be Addressed in Procuring Simulators

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	1. CRUCIAL--the issue must be addressed	2. EXTREMELY USEFUL--the issue should be addressed	3. USEFUL--the issue probably should be addressed	4. OPTIONAL--the issue might be addressed	5. TRIVIAL--the issue need not be addressed	1. issue ALMOST ALWAYS has been addressed in the past	2. issue FREQUENTLY has been addressed in the past	3. issue OCCASIONALLY has been addressed in the past	4. issue INFREQUENTLY has been addressed in the past	5. issue ALMOST NEVER has been addressed in the past
1. Verify that course objectives are met with the simulator system										
2. Evaluate the training effectiveness of the simulator system by testing student performance										
3. Verify all costs associated with the simulator are within estimates										
4. Establish and monitor time schedules for development and installation of the simulator										
5. Insure provisions for updates and changes										
6. Insure that adequate tools, documentation, spare parts, and personnel are available for repair of the simulator										

Table III (continued)

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. ALMOST ALWAYS addressed	2. FREQUENTLY addressed	3. OCCASIONALLY addressed	4. INFREQUENTLY addressed	5. ALMOST NEVER addressed
7. Verify that actual repair frequency and "downtime" are within estimates										
8. Insure the training site is adequately prepared for installation of simulator										
9. Establish and monitor time schedules for NAMTRADET course										
10. Establish follow up procedures to monitor instructor and student attitudes toward the simulator system										
11. Insure adequacy of instructor training for use of simulator system										
12. Insure adequate human factors design requirements have been met										
13. Evaluate instructor performance										
14. Establish effective channels of communication between instructors and management										
15. Assess all effects resulting from introduction of simulator system										
16. Prevent overuse of the simulator as a toy to impress visiting dignitaries										
Add new items here										

Instructions for Completing Section III

Results. Question V of Questionnaire One asked you to rate the feasibility, the training effectiveness, and the cost of simulation for nine aircraft systems. The opinions of all participants are summarized in two tables given in this section.

In these tables each entry gives the percentage of experts selecting that alternative for a given category, such as feasibility. For example, for the Organizational Level table for Structures, Hydraulics, & Flight Controls, under the category feasibility, 59% of the experts said simulation was Definitely feasible, 20% said simulation was Possibly feasible,..., and 5% said simulation was Definitely infeasible (see table). The percentages add to 101%, rather than 100%, because each percentage was rounded off to the nearest whole number. For the same system and maintenance level (see table), 18% of the experts stated that simulators were Much more effective for training, 46% stated that simulators were Possibly more effective, 10% stated that simulators and operational equipment were Equally effective,....

Delphi. As discussed earlier, the Delphi Technique obtains the independent opinions of experts, summarizes those opinions, and then asks each expert to reconsider his opinion in light of the opinions of all the experts. The aim of the technique is to obtain agreement among the experts, if such agreement actually exists. Agreement is indicated by a high percentage (perhaps 50% or more) of the experts selecting the same alternative, such as the 59% selecting Definitely feasible.

The Delphi Technique is similar to a conference in which each expert presents his independent opinion on the topic and then, after having heard the opinions of other experts, he is given the opportunity to change his opinion.

Illustration of Instructions. In Question V of Questionnaire One, in two tables, you gave your opinions on simulators and operational equipment. Now you are asked to reexamine your opinions in the light of the opinions of the group, and if you desire, change your opinions. An example will illustrate how to change or retain your opinion.

Here is a portion of the table for Organizational Level Maintenance:

	Feasibility					Training Effectiveness					Cost Effectiveness				
	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
Structure, Hydraulics, & Flight Controls	59	20	10	7	5	18	46	10	23	3	3	8	13	50	26
Propulsion	37	29	10	12	12	15	30	17	20	17	3	14	19	32	35

[The column headings (e.g., Definitely feasible) have been omitted here. Refer to the complete table for the headings.]

In the above table, the circles in red indicate the judgements of one expert in Questionnaire One. (On the complete tables the opinions you gave are indicated by the red circles.) Thus, for Structures, Hydraulics, & Flight Controls, this expert judges that simulation was 1. Definitely feasible, that operational equipment and simulators were 3. Equally effective for training, and that simulators were 2. More expensive than operational equipment.

In the category Feasibility, the expert examines the percentages representing all the experts and decides to retain his original opinion, 1. Definitely feasible. He therefore makes no mark on the table. He also decides to retain his original opinion on Training Effectiveness, namely, 3. Equally effective. On Cost Effectiveness he decides to change his opinion (Simulators are 2. More expensive) to the opinion that simulators are 4. Less expensive. He indicates this new opinion by placing an X in the box 4. Less expensive.

For the Propulsion system the expert retains his former opinions on Feasibility and Training Effectiveness, but for Cost Effectiveness he changes his opinion from 1. Much more expensive to 2. More expensive and indicates this change by marking an X in the box 2. More expensive.

If he cares to, the expert may provide a comment on the back of the sheet explaining why he did or did not change his opinion. Such comments are particularly helpful if the expert's opinion differs greatly from the opinion of the group.

You are under no obligation to agree with the other experts. If an honest difference of opinion exists among the experts, we want the results of the questionnaire to reflect that difference of opinion.

Summary of Instructions to Complete Two Tables

1. The table entries give the percentage of experts expressing a given opinion (e.g., 59% of the experts said Definitely feasible).

2. The red circles indicate the opinions you expressed on Questionnaire One.

3. Examine the table entries for each aircraft system and category and decide if you want to retain or change your opinion.

If you want to retain the same opinion you gave on Questionnaire One, make no mark on the table.

If you want to change your opinion, put an X in the appropriate box.

4. If your opinion differs from the general opinion of the group, if you can, please provide a comment on the back of the table to support your opinion or to refute the majority opinion.

Brief Descriptions of Aircraft Maintenance Systems

Structure, Hydraulics and Flight Controls Systems--includes for example: airframe structure components, corrosion control, hydraulic power supply and distribution systems, alighting and launching gear, wing and fin foil systems, primary and secondary flight control systems, empennage.

Propulsion Systems--includes for example: engine maintenance, quick engine change, assembly and buildup, removal/installation, aircraft fuel storage and transfer, fuel system operation and maintenance.

Electrical and Instrument Systems--includes for example: drive generator, electrical power supply and distribution, instrument indicating systems, lighting, and electrical circuits for following systems: engine and related system, hydraulic, environmental, life support, armament.

Environmental Control and Egress Systems--includes for example: cabin air conditioning, cabin air pressurization, crew egress component/subsystems, oxygen system.

Armament/Weapons Delivery System--includes for example: guns, mounts, weapon direction equipment, launcher, pods, bomb racks and other mechanical or electro-mechanical equipment for weapons delivery function.

Communications and Navigation Systems--includes for example: intercom, radio system(s), data link, radar, radio, direction finding set, doppler compass.

Automatic Flight Controls--includes for example: automatic pilot, flight displays, mechanical and electrical parts for signal transmission and application of power, reference sensors, air data computer.

Reconnaissance Equipment--equipment necessary to reconnaissance mission. Includes for example: photographic and electronics, infrared and other sensors, search receivers, recorders, warning devices, magazines and data link.

Anti-Submarine Warfare--equipment preculiar to the anti-submarine warfare mission. Includes for example: acoustic and nonacoustic sensor systems, computer, displays.

ORGANIZATIONAL LEVEL

(Refer to earlier descriptions for distinctions between O-level and I-level maintenance)

	Totally ignorant of this system	The simulation of most or all of this system is:					Compared to operational equipment simulators are:									
		1. Definitely feasible	2. Possibly feasible	3. Uncertain	4. Possibly infeasible	5. Definitely infeasible	1. Much more effective for training	2. Possibly more effective	3. Equally effective	4. Possibly less effective	5. Much less effective	1. Much more expensive	2. More expensive	3. Equally expensive	4. Less expensive	5. Much less expensive
Structure, Hydraulics, & Flight Controls		59	20	10	7	5	18	46	10	23	3	3	8	13	50	26
Propulsion		37	29	10	12	12	15	30	17	20	17	3	11	19	32	35
Electrical & Instrument		79	16	2	2	0	47	28	9	14	2	0	2	15	51	32
Environmental/Egress		46	36	10	5	3	14	38	16	24	8	0	9	17	51	23
Armament/Weapons Delivery		57	25	10	3	5	33	27	20	13	7	0	8	5	55	32
Communications and Navigation		71	15	5	7	2	46	24	7	12	10	0	5	15	37	43
Automatic Flight Controls		57	29	12	2	0	43	29	14	12	2	0	0	10	61	30
Reconnaissance		43	38	5	11	3	27	30	14	24	5	0	8	14	49	30
Antisubmarine Warfare		66	18	8	5	3	34	29	16	16	5	0	5	11	50	34

INTERMEDIATE LEVEL

(Refer to earlier descriptions for distinctions between O-level and I-level maintenance)

	Totally ignorant of this system	The simulation of most or all of this system is:					Compared to operational equipment simulators are:									
		1. Definitely feasible	2. Possibly feasible	3. Uncertain	4. Possibly infeasible	5. Definitely infeasible	1. Much more effective for training	2. Possibly more effective	3. Equally effective	4. Possibly less effective	5. Much less effective	1. Much more expensive	2. More expensive	3. Equally expensive	4. Less expensive	5. Much less expensive
Structure, Hydraulics, & Flight Controls		27	10	23	20	20	13	26	3	26	33	6	11	28	36	19
Propulsion		23	15	23	17	23	10	28	3	26	33	3	16	22	35	24
Electrical & Instrument		56	10	13	13	8	35	20	7	23	15	0	13	15	46	26
Environmental/Egress		27	14	22	14	24	19	22	6	28	25	3	9	18	44	26
Armament/Weapons Delivery		36	17	11	22	14	25	19	6	25	25	0	14	20	40	26
Communications and Navigation		45	15	10	20	10	36	15	5	21	23	0	15	18	41	26
Automatic Flight Controls		36	18	18	18	10	29	16	8	26	21	3	16	16	42	24
Reconnaissance		35	19	16	19	11	28	22	3	25	22	0	16	19	41	24
Antisubmarine Warfare		46	11	14	19	11	31	14	14	8	22	0	19	11	41	30

Before mailing,

Please check to see that you have written your name on the first page of each table and that you have included all the tables of Questionnaire Two.

Table I	(6 pages)
Table II	(3 pages)
Table III	(2 pages)
Table for Organizational Level	(1 page)
Table for Intermediate Level	(1 page)

APPENDIX E

Questionnaire Three and the material provided with Questionnaire Three

Dear _____

Thank you for completing Questionnaire Two in our study of simulators and operational equipment in aviation maintenance training.

Questionnaire Three is enclosed. It is, you will be happy to hear, the last questionnaire of the study. The time required to complete Questionnaire Three should be much less than that required for either of the two previous questionnaires.

We would be grateful for any comments about Questionnaire Three or earlier questionnaires, or about this method for obtaining expert opinion. Write your comments on a separate sheet of paper. This is your last chance to voice your thoughts about the problem of simulators versus operational equipment. You will be sent a copy of the final report of this study as soon as it is completed.

Once again I must ask you to return the questionnaire promptly, within a few days if possible. A quick response will save me (and you) the time spent on a reminder phone call and will mean you will have the final report sooner.

Once again, thanks for your cooperation in this study.

Sincerely,

ROBERT M. HERRICK

Questionnaire Three

In Questionnaire Three, you are to reexamine the opinions you expressed in Questionnaire Two and also give your opinion on a few new items. In completing this questionnaire remember that this study:

a) is limited to maintenance training at NAMTRADETS,

b) includes both O-level and I-level (but not depot level) maintenance training, and

c) is limited to simulation systems that cost no more than $200,000.

Results. Tables I, II, and III show, for each item and category of Questionnaire Two, the percentage of experts that selected each alternative. For example, consider in Table I, item 1. "A detailed description of each task the student must perform." In Questionnaire Two for this item (see Table I), under the category Need for Information, 73% of the experts selected the alternative CRUCIAL, 13% selected the alternative EXTREMELY USEFUL, ..., and 0% selected the alternative TRIVIAL.

For each item, for each category, the alternative that you selected in Questionnaire Two is indicated by a red circle.

Instructions. These instructions for completing Questionnaire Three are similar to those you followed for the O-level and I-level tables of Questionnaire Two.

For each item of Tables I, II, and III examine the percentage data and decide if you want to change or retain your opinion.

If you want to retain the opinion you gave on Questionnaire Two, make no mark for that item.

If you want to change your opinion, put an X in the box for the new alternative you have chosen.

If your opinion differs from the general opinion of the group, if you can, please provide a comment on the back of the table to support your opinion or to refute the majority opinion.

When examining Table I, recall that a row labelled "S" means that the device referred to in the item is a simulator, and a row labelled "O" means that the device referred to in the item is operational equipment.

When new items have been added, they appear at the end of a table. To indicate your opinion for each new item, mark an X under one of the five alternatives for each category.

NAME_____

Section I. Gathering Information to Help the Decision Maker Decide between Simulators and Operational Equipment.

Table I. Information Required for Decision Making

Item of Information	Need for information					Effort required to obtain information				
	1. CRUCIAL--the information must be obtained	2. EXTREMELY USEFUL--the information should be obtained	3. USEFUL--the information probably should be obtained	4. OPTIONAL--the information might be obtained	5. TRIVIAL--the information need not be obtained	1. requires LITTLE EFFORT to obtain information	2. requires SLIGHT EFFORT to obtain information	3. requires MODERATE EFFORT to obtain information	4. requires MAJOR EFFORT to obtain information	5. requires EXTREME EFFORT to obtain information
COURSE CONTENT CONSIDERATIONS										
1. A detailed description of each task the student must perform	73	13	8	6	0	10	8	25	42	15
2. The time it should take the student to perform each task	10	38	37	8	8	4	18	43	29	6
3. The tools, test equipment, and documentation available to the student during training and testing	62	38	2	0	0	19	35	35	6	6
4. The criteria used to evaluate the student's performance for each task	56	19	21	4	0	10	25	35	23	8
5. The training objectives of the course	83	8	8	0	2	18	25	33	24	0
6. The amount of supervision provided on the job	6	37	38	13	6	23	35	35	4	4

Table I (continued)

Item of information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
7. A description of the physical environment on the job (e.g., heat, noise)		8	25	44	17	6	31	37	25	8	0
8. The physical fidelity (e.g., size, weight) required to meet the course objectives		38	21	35	2	4	13	37	25	10	15
9. The availability of other courses which might meet the objectives of the planned course		35	33	25	6	2	21	27	44	4	4
10. The availability of instructional aids (e.g., lesson plans, movies)		25	37	29	4	6	15	21	46	13	4
11. The amount of feedback to the instructor about student performance		38	42	13	6	0	2	25	46	17	10
12. The amount of feedback to the student about his performance		38	37	17	4	4	4	31	46	13	6
13. Analysis of frequent failures and repairs of the weapon system		37	42	21	0	0	4	14	39	29	14
14. The tools, test equipment, and documentation available to the student to perform each task on the job		54	33	12	0	2	15	35	29	21	0
15. List of malfunctions (faults) that the maintenance man must recognize and correct on the job		65	27	6	2	0	4	8	48	29	10
16. Lists of faults that can and cannot be inserted into the device	S	57	29	10	2	2	12	13	33	37	6
	0	55	29	10	6	0	4	8	46	31	12
17. The need to demonstrate multiple faults for a single failure		34	36	30	0	0	6	12	44	29	10
18. The need to include infrequently encountered maintenance tasks		20	30	28	20	2	4	12	53	25	6
19. The requirement for "hands-on" experience		63	23	12	2	0	13	17	42	25	2
20. The amount and type of additional training required on the job		29	42	23	4	2	4	19	44	25	8

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
21. The need for self-paced learning		18	29	18	27	8	4	16	36	24	20
22. The need for alternative routes (i.e., branching) for learning		20	29	27	16	8	4	12	42	32	10
ECONOMIC CONSIDERATIONS											
23. The funds available for the project		87	9	4	0	0	27	38	18	9	9
24. The cost to buy each device	S	85	12	4	0	0	8	20	35	22	16
	O	81	6	12	0	0	18	41	27	8	6
25. The cost for spare parts for each device	S	65	31	4	0	0	6	18	39	25	12
	O	63	29	8	0	0	12	29	39	12	8
26. The cost to transport and install each device	S	44	23	25	6	2	12	51	27	8	2
	O	46	19	27	6	2	14	45	35	6	0
27. The cost to modify NAMTRADET facilities to use device	S	60	23	15	2	0	6	19	44	23	8
	O	60	25	15	0	0	6	21	54	15	4
28. Power and related costs to operate each device	S	42	27	19	8	4	13	38	37	8	4
	O	48	25	19	4	4	12	38	40	8	2
29. The cost for the routine maintenance of each device	S	60	23	15	2	0	2	15	54	15	13
	O	60	21	15	2	2	6	25	54	10	6
30. The cost to repair each device if it malfunctions	S	57	35	8	0	0	2	10	33	35	20
	O	55	33	8	2	2	2	22	37	27	12
31. The cost to update each device as changes occur in the weapon system	S	65	25	8	2	0	2	4	46	29	19
	O	71	19	6	4	0	2	8	48	27	15
32. The cost and number of instructors and support personnel with each device	S	71	21	6	0	2	0	31	49	6	14
	O	71	23	4	0	2	4	29	49	8	10
LIFE CYCLE CONSIDERATIONS											
33. Political preferences for different devices	S	18	20	24	12	24	14	10	47	8	10
	O	14	18	27	16	24	20	10	43	16	10

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
34. The expected life of the weapon system		46	38	15	0	0	4	23	40	23	10
35. For a new weapon system, the delivery dates for fleet introduction		54	33	6	6	2	8	37	33	17	6
36. The number of maintenance personnel required to support the weapon system		52	29	13	6	0	4	28	48	19	0
37. The time available to train the personnel required to support the weapon system		60	27	8	4	2	8	19	48	19	6
38. The length of time required to procure, deliver, and install the device	S	69	25	6	0	0	8	15	42	33	2
	O	75	19	6	0	0	8	17	46	25	4
39. The availability of information needed to develop a training course		57	37	4	0	2	4	10	41	29	16
40. The anticipated frequency and complexity of modifications of the weapon system		35	42	19	4	0	0	4	25	43	27
41. The anticipated capabilities of simulators in the next few years		35	23	31	8	4	2	8	35	37	19
REPAIR CONSIDERATIONS											
42. Estimates of frequency of repair for each device	S	46	42	10	0	2	4	12	37	35	13
	O	50	44	4	0	2	2	12	48	35	4
43. Estimates of average time to repair each device	S	33	50	15	0	2	4	12	46	29	10
	O	40	46	12	0	2	4	13	54	25	4
44. Requirements for special tools and test equipment to repair each device	S	52	29	17	0	2	6	23	44	15	12
	O	52	31	15	0	2	8	35	42	13	2
45. Requirements for specially trained people to repair each device	S	54	40	4	0	2	10	19	46	19	6
	O	48	37	10	0	6	15	17	42	19	6

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
46. Requirements for special documentation to repair each device	S	30	28	32	6	4	12	22	34	24	8
	O	24	24	43	6	4	16	30	32	18	4
47. Availability of spare parts if device requires repair	S	62	25	13	0	0	8	24	31	27	10
	O	56	27	15	2	0	14	31	33	16	6
48. Extent of factory support required to repair device	S	48	38	8	6	0	8	27	33	27	6
	O	42	42	12	2	2	14	26	42	16	2
49. The accessibility of components of device requiring repair	S	25	23	44	6	2	6	37	37	12	8
	O	23	23	46	4	4	10	41	41	6	2
PHYSICAL CONSIDERATIONS											
50. The dimensions and weight of the device	S	19	23	40	12	6	46	31	19	2	2
	O	25	29	33	10	4	48	29	17	4	2
51. The electrical or other power requirements for each device	S	31	29	27	8	6	42	35	17	4	2
	O	38	27	25	6	4	44	31	19	4	2
52. The problems associated with moving and storing each device	S	13	25	38	15	8	27	39	25	6	2
	O	13	29	40	12	6	25	48	23	4	0
53. The durability of each device under frequent use	S	44	46	6	4	0	8	27	31	22	12
	O	44	46	6	4	0	6	30	46	14	4
54. The number of sites where each device will be used	S	37	29	27	6	2	31	42	19	6	2
	O	37	29	27	4	4	33	40	19	6	2
55. The number of students who could use each device at the same time	S	43	43	12	2	0	25	38	29	8	0
	O	41	47	10	2	0	21	42	27	8	2
56. The number of students to be trained with the device in one year	S	42	44	6	4	4	12	43	25	18	2
	O	46	42	4	4	4	12	45	24	18	2
57. The duration of the course		22	32	34	5	7	39	31	23	8	0
58. The percentage of the class time the device will be used	S	25	42	19	12	2	19	23	37	19	2
	O	27	42	19	10	2	17	25	37	17	4

Table I (continued)

Item of Information		Need for information					Effort required to obtain information				
		1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. LITTLE EFFORT	2. SLIGHT EFFORT	3. MODERATE EFFORT	4. MAJOR EFFORT	5. EXTREME EFFORT
59. The class time that might be saved with each device	S	27	57	12	4	0	0	8	46	40	6
	O	24	59	12	6	0	0	6	48	40	6
60. The scheduling flexibility of the course (i.e., what will happen if the device is inoperative?)	S	57	27	14	2	0	0	20	54	18	8
	O	53	31	14	2	0	0	22	57	14	8
CONSIDERATIONS ABOUT INSTRUCTORS AND STUDENTS											
61. The extent of instructor's experience working with maintenance of the system		14	31	35	12	8	24	33	33	10	0
62. The extent of the instructor's experience teaching the course		16	18	47	12	8	31	35	29	4	0
63. The attitudes of instructors about each device	S	41	25	22	6	6	16	18	43	16	6
	O	31	24	29	8	8	16	27	39	12	6
64. The amount of training of instructors required to use each device	S	39	39	20	2	0	12	32	38	18	0
	O	39	31	25	2	2	18	32	40	10	0
65. The educational background of potential students		29	31	22	14	4	24	35	25	14	2
66. The maintenance experience of potential students		27	22	31	16	4	24	22	37	16	2
67. The attitudes of students about each device	S	27	16	31	16	10	8	27	39	16	10
	O	22	14	37	18	10	10	24	43	12	10
New Items: The likelihood that the students may damage the device	S										
	O										
The likelihood that the device may cause injury to the student	S										
	O										
The capability of the device for demonstrating safety procedures	S										
	O										
The ability of the device to duplicate actual operating conditions	S										
	O										

NAME_____

Section I. Gathering Information to Help the Decision Maker Decide between Simulators and Operational Equipment.

Table I. Information Required for Decision Making

Item of Information	Need for information					Effort required to obtain information				
	1. CRUCIAL--the information must be obtained	2. EXTREMELY USEFUL--the information should be obtained	3. USEFUL--the information probably should be obtained	4. OPTIONAL--the information might be obtained	5. TRIVIAL--the information need not be obtained	1. requires LITTLE EFFORT to obtain information	2. requires SLIGHT EFFORT to obtain information	3. requires MODERATE EFFORT to obtain information	4. requires MAJOR EFFORT to obtain information	5. requires EXTREME EFFORT to obtai information
COURSE CONTENT CONSIDERATIONS										
1. A detailed description of each task the student must perform	73	13	8	6	0	10	8	25	42	15
2. The time it should take the student to perform each task	10	38	37	8	8	4	18	43	29	6
3. The tools, test equipment, and documentation available to the student during training and testing	62	38	2	0	0	19	35	35	6	6
4. The criteria used to evaluate the student's performance for each task	56	19	21	4	0	10	25	35	23	8
5. The training objectives of the course	83	8	8	0	2	18	25	33	24	[illegible]
6. The amount of supervision provided on the job	6	37	38	13	6	23	35	35	4	4

NAME_____

Table II. Sources of Information for Decision Making

Source of Information	Need to consult				
	1. MANDATORY--must be consulted	2. PROBABLY VERY USEFUL--should be consulted	3. USEFUL--probably should be consulted	4. OPTIONAL--might be consulted	5. UNNECESSARY--need not be consulted
PERSONNEL					
1. Instructors of the course	71	21	8	0	0
2. Instructors teaching similiar courses	19	35	33	13	0
3. Instructors who are teaching with simulators	27	42	21	10	0
4. Training analysts	44	23	17	10	6
5. Personnel doing the maintenance job in the fleet	44	29	19	8	0
6. Graduates of the course	14	35	29	20	2
7. Students of the course	10	18	33	29	10
8. Aircraft manufacturer	17	37	15	21	10
9. Manufacturers of aircraft components	8	33	14	24	22

Table II (continued)

Source of Information	Need to consult				
	1. MANDATORY	2. PROBABLY VERY USEFUL	3. USEFUL	4. OPTIONAL	5. UNNECESSARY
10. Navy supply specialists	12	29	35	15	10
11. Navy procurement specialists	23	17	42	12	6
12. Navy safety specialists	24	27	35	12	2
13. Manufacturers of simulators	52	23	17	6	2
14. Navy school administrators	27	31	29	12	2
15. Navy management	28	32	16	20	4
DOCUMENTS					
16. Maintenance manuals for the weapon system	92	8	0	0	0
17. Flight manuals of the weapon system	54	22	8	10	6
18. Maintenance Plan (i.e., written record of maintenance concept for system and equipment, including maintenance tasks, level of repair analysis, and support and test equipment requirements)	88	10	2	0	0
19. Personnel and Training Plan (i.e., written record of personnel and training required to operate and support the equipment)	73	12	12	4	0
20. Technical Data Plan(i.e., written description of all information aids necessary to operate and support the equipment)	63	27	10	0	0
21. Facilities Requirements Plan (i.e., written record of shipboard, shore, operational, maintenance, and training facilities)	38	42	16	4	0
22. Transportation and Handling Plan (i.e., written record of packaging, handling, storage, and transportation requirements for equipment)	19	23	42	6	10

Table II (continued)

Source of Information		Need to consult				
		1. MANDATORY	2. PROBABLY VERY USEFUL	3. USEFUL	4. OPTIONAL	5. UNNECESSARY
23.	Relevant government instructions	38	25	25	10	2
24.	Research and evaluation reports on maintenance simulators	49	22	22	8	0
New items	Research personnel experienced with simulators used for training					
	Companies with the potential for manufacturing simulators					

AD-A052 715 NAVAL AIR DEVELOPMENT CENTER WARMINSTER PA AIRCRAFT --ETC F/G 5/9
SIMULATORS IN AVIATION MAINTENANCE TRAINING: A DELPHI STUDY.(U)
DEC 77 R M HERRICK, J B WRIGHT

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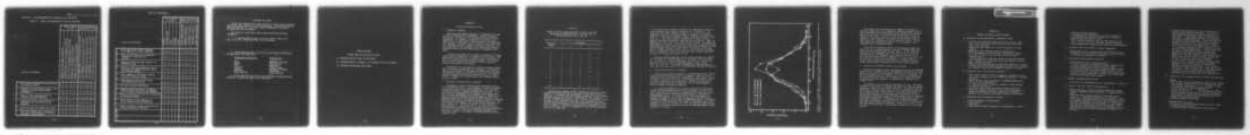

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Section II. The Implementation of a Decision to Use Simulators.

Table III. Issues to be Addressed in Procuring Simulators

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	1. CRUCIAL--the issue must be addressed	2. EXTREMELY USEFUL--the issue should be addressed	3. USEFUL--the issue probably should be addressed	4. OPTIONAL--the issue might be addressed	5. TRIVIAL--the issue need not be addressed	1. issue ALMOST ALWAYS has been addressed in the past	2. issue FREQUENTLY has been addressed in the past	3. issue OCCASIONALLY has been addressed in the past	4. issue INFREQUENTLY has been addressed in the past	5. issue ALMOST NEVER has been addressed in the past
1. Verify that course objectives are met with the simulator system	96	2	0	0	2	18	14	37	20	12
2. Evaluate the training effectiveness of the simulator system by testing student performance	83	15	0	2	0	24	12	25	22	18
3. Verify all costs associated with the simulator are within estimates	44	33	17	2	4	12	30	26	18	14
4. Establish and monitor time schedules for development and installation of the simulator	44	38	15	0	2	22	39	25	10	4
5. Insure provisions for updates and changes	65	33	2	0	0	10	27	31	12	20
6. Insure that adequate tools, documentation, spare parts, and personnel are available for repair of the simulator	78	20	2	0	0	8	33	24	18	18

Table III (continued)

Issue to be addressed	Need to address an issue					Past performance in addressing an issue				
	1. CRUCIAL	2. EXTREMELY USEFUL	3. USEFUL	4. OPTIONAL	5. TRIVIAL	1. ALMOST ALWAYS addressed	2. FREQUENTLY addressed	3. OCCASIONALLY addressed	4. INFREQUENTLY addressed	5. ALMOST NEVER addressed
7. Verify that actual repair frequency and "downtime" are within estimates	29	41	27	0	2	6	20	33	29	12
8. Insure the training site is adequately prepared for installation of simulator	67	29	4	0	0	25	25	35	8	8
9. Establish and monitor time schedules for NAMTRADET course	31	33	27	4	4	23	33	29	6	8
10. Establish follow up procedures to monitor instructor and student attitudes toward the simulator system	25	40	31	2	2	6	19	19	31	25
11. Insure adequacy of instructor training for use of simulator system	67	21	8	2	2	10	21	35	29	6
12. Insure adequate human factors design requirements have been met	37	50	8	4	2	6	17	38	27	12
13. Evaluate instructor performance	40	37	19	2	2	13	31	21	13	21
14. Establish effective channels of communication between instructors and management	38	38	12	10	2	10	27	33	22	8
15. Assess all effects resulting from introduction of simulator system	27	57	12	2	2	8	12	24	22	35
16. Prevent overuse of the simulator as a toy to impress visiting dignitaries	21	19	33	12	15	2	4	21	23	50
New items: Establish programs to teach instructors how to use simulators for training										

Personnel Data Sheet

In the final report on this study we want to identify the participants and provide some information on their backgrounds. (The opinions and comments you provided will, of course, remain confidential; no name will be associated with any comment.)

For inclusion in the final report please provide the following information.

1. In the space below, type or print your rank or other title (e.g., Dr., Prof., ATCS), your name, and your address.

2. Please check one item in the list of institutional affiliations and one item in the list of jobs.

Institutional Affiliation	Principal Job
Navy	NAMTRADET instructor
Marines	Administrator
Army	Researcher
Air Force	Project leader
Industry	University professor
University	Consultant
Other (specify)	Other (specify)

3. Briefly describe the extent of your knowledge or experience with simulators, including the names of the simulators.

Before mailing,

Please check to see that you have:

a) completed the new items in the tables

b) enclosed Tables I (6 pages), II (3 pages), and III (2 pages)

c) enclosed the Personnel Data Sheet.

APPENDIX F

Statistical analyses of data

1. Problem of consensus

One aim of the Delphi technique is to determine the items on which the experts are in agreement. Complete agreement would occur, of course, if all the experts selected the same alternative. For example, in response to an item, if the experts were to select one of five alternatives (varying from, say, "crucial" to "trivial") and all selected, say, alternative two ("extremely useful"), complete agreement would exist. On the other hand, if the responses of the experts were randomly distributed among the five alternatives, no agreement would exist.

To specify precisely what is meant by consensus of opinion some statistical definition of consensus must be derived. Some authors have concluded that a consensus of opinion existed if 50% of the experts selected the same category. Other authors have used more sophisticated measures to define consensus, usually some measure of variability.

Consideration of the problem of defining consensus suggests that two crucial variables must be considered: the number of experts participating and the number of alternatives available. The essential question is whether the division of the experts' responses among the several alternatives is likely to occur by chance. If chance is a likely outcome, then consensus cannot be said to exist.

2. Probability considerations on consensus

Evaluation of chance outcomes may be determined with the aid of probability theory. The assignment of experts' responses to alternatives may be considered analogous to the classical probability scheme of randomly assigning balls to urns. If we have five urns (representing five response alternatives) and, say, 20 balls (representing the selections of 20 experts), how would the balls be randomly distributed among the urns? Ten computer simulations of the problem (20 balls randomly distributed among five urns) gave the results indicated in Table F-1. Table F-1 indicates, for example, that in the seventh simulation, of the 20 balls, two balls fell in Urn No. 1, one in Urn No. 2, nine in Urn No. 3, three in Urn No. 4, and five in Urn No. 5. This simulation is analogous to two experts selecting alternative one (e.g., "crucial"), one expert selecting alternative two ("extremely useful"), nine experts selecting alternative three ("useful"), etc..

Table F-1

Number of balls randomly assigned to each of five urns assuming equal probability (p = .20) that any of the 20 balls will fall in any urn

Simulation number	Urn number				
	1	2	3	4	5
1	3	3	5	6	3
2	6	3	3	4	4
3	1	7	4	4	4
4	6	5	5	0	4
5	1	8	2	5	4
6	0	2	3	8	7
7	2	1	9	3	5
8	6	4	3	2	5
9	3	3	5	7	2
10	4	5	3	3	5

Continuing the analogy further, statistical measures of central tendency and variability may be computed for each row of data in Table F-1. To perform such computations, assume that the Urn Numbers represent scores; thus, Urn No. 1 represents a score of value 1, Urn No. 2 represents a score of value 2, Urn No. 3 represents a score of value 3, etc. Assume further that a score stands for a class interval that extends half a unit below and above its nominal value. Thus, a score of 1 represents a class interval extending from 0.5 to 1.5 (or 1.4999), a score of 2 represents a class interval extending from 1.5 to 2.4999, etc.

To describe the situation in terms of the responses of experts to a questionnaire item, consider Simulation No. 7 of Table F-1. In this case, two experts selected category 1 ("crucial"), and each received a score of 1; one expert selected category 2 and received a score of 2; nine experts selected category 3 and each received a score of 3, etc.. From this frequency distribution of scores, one may compute statistical measures to summarize the distribution. Thus, the mean score is (2x1 + 1x2 + 9x3 + 3x4 + 5x5)/20 or 3.40. The median or 50th percentile, namely, the point below which fall 10 scores and above which fall 10 scores, occurs within the class interval nominally called score 3, namely, between 2.50 and 3.4999. Since three scores fall below 2.5, and nine scores fall within the class interval, the median is 2.5 + (7/9)(1) or 3.278. Thus, for this row of data of Table F-1, the mean is 3.40 and the median is 3.278.

Following similar reasoning, one may compute measures of variability for each row of data of Table F-1. For example, for Simulation No. 7 of Table F-1, the 25th percentile (P_{25}) is 2.722 and the 75th percentile (P_{75}) is 4.500, so the interquartile range, namely, $P_{75} - P_{25}$, is 1.778. [The smallest interquartile range possible is 0.50, and this would occur if all selections were the same alternative.]

3. Statistical definition of consensus

Following the procedure described in the preceding section, simulations were performed with the aid of a computer. The goal of the simulations was to determine what interquartile ranges would be likely to result on the basis of chance. Such interquartile ranges, would, of course, indicate a lack of consensus. However, smaller interquartile ranges, below those likely to occur by random assignment, can be considered examples of consensus.

All simulations employed five response alternatives (five urns), because the questionnaire items had five categories. In one set of 1,000 simulations, the number of "judgments"(balls) used in each simulation was 35, which corresponded approximately to the number of NON-NAMTRADET experts. In another set of 1,000 simulations, the number of "judgments" used in each simulation was 25, which corresponded approximately to the number of NAMTRADET experts. In addition, in a set of 1,000 simulations, the number of "judgments" used in each simulation was 20, as in Table F-1. This last set of simulations was included to represent cases where some of the NAMTRADET experts failed to respond to an item.

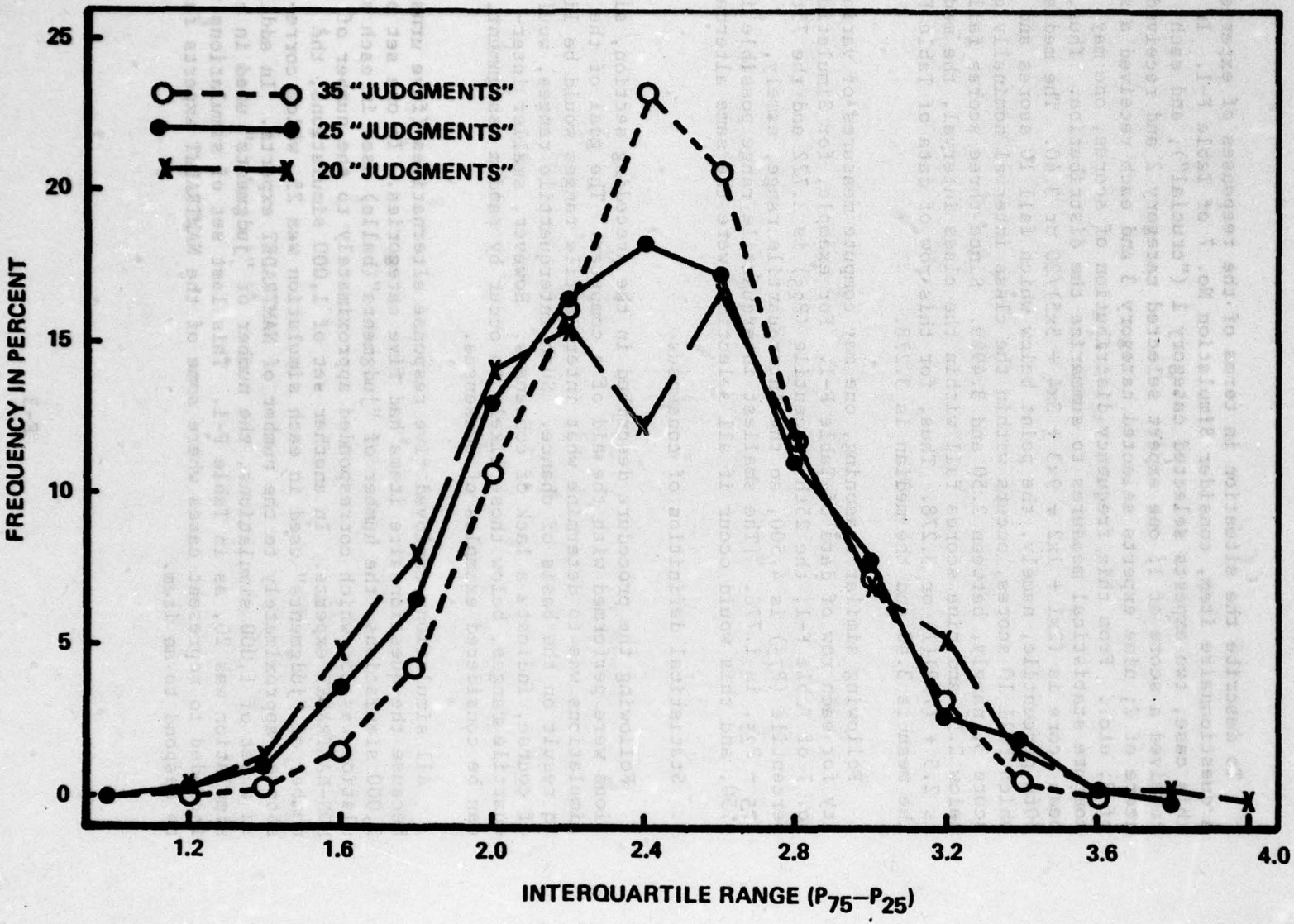

Figure F-1. Distributions of interquartile ranges derived from Monte Carlo simulations with five response categories. Each distribution represents 1,000 simulations.

The results of the simulations are summarized in Figure F-1. Figure F-1 shows that, with "judgments" randomly assigned to any of five alternatives, the interquartile range typically falls between about 1.80 and 3.00. The cut-off point, selected as an index of consensus, was 1.2999. That is, in the present study, if the responses to a questionnaire item yielded an interquartile range of less than 1.30, a consensus of opinion was said to exist. If the item yielded an interquartile range of 1.30 or greater, it was concluded that no consensus existed.

This index of consensus, namely, an interquartile range less than 1.30, is a stringent measure, selected to exclude almost all cases where the results might occur by chance. In the 1,000 simulations with 35 "judgments" none fell below 1.30; in the 1,000 simulations with 25 "judgments", only three fell below 1.30; in the 1,000 simulations with 20 "judgments", only four fell below 1.30. The selection of such an extreme measure of consensus means, of course, that a questionnaire item on which a consensus of opinion really existed might be classified as an item of non-consensus.

4. Evaluation of difference between the two groups

For each questionnaire item, the difference between the NAMTRADET distribution of judgments and the NON-NAMTRADET distribution of judgments was evaluated by the Kolmogorov-Smirnoff (K-S) two-sample test. The K-S two-sample test "is sensitive to any kind of difference in the distribution from which the two samples were drawn--differences in location (central tendency), in dispersion, in skewness, etc." (Siegel, 1956).

Occasionally, not all experts responded to an item. This minor variation in the number of responses was ignored in order to simplify comparisons between the two groups of experts. Also ignored was the difference in the two sample sizes, since this difference would have only a small influence on the outcome. The comparison between the two distributions for a questionnaire item was considered to be statistically significant if the difference between the two cumulative percentage distributions differed by 40 percentage points or more at any response alternative. A difference of 40 percentage points represents a difference significant at the .05 level, two-tailed test, when each sample contains 25 responses. (With $n_1 = n_2 = 30$, at the .05 level, two-tailed test, the difference required is 37 percentage points.)

APPENDIX G

Summary of comments made by experts

A. Evaluation of and skepticism of comments of others

--"I would have liked many times to have said I didn't really know - but I know that I know better than most people who will be less reticent."
--"Maybe the other experts are wrong and ignorance is being pooled."
--"These kats don't know what they are talking about."
--"My best response is that you have a mixed bag of respondents, many of whom do not know where the cost savings leverage rests."
--"I am stunned that so many are willing to state the effectiveness of simulators is so much better than operational equipment. Where is the data?"
--"Where do all these guys get the idea that simulation is cheap?"
--"I would question the actual experience of some of the responders with regard to operational equipment designed for training."

B. Discussion about "the decision" objective

--"Many items I marked trivial are <u>crucial</u> in determining training course strategies but don't affect the simulator v. hardware decision."
--"Most 'trivial' items are germane to NAMTRAGRU Headquarters, not Chief of Naval Material."
--"I think other people responded to general course planning, not specific decisions."
--"I found it hard to keep the overall objective in mind."
--"These are important questions to the actual development of maintenance trainers--but don't appear very necessary to making a choice between operational equipment or simulators."

C. Difficulty with interpretation of items

--"Answer depends on interpretation."
--"Too specific."
--"Bad term."
--"Question and answer contingent on interpretation of 'need'."

--"Question somewhat ambiguous."
--"I interpret this as Congress not as school commander."
--"I am assuming you mean the evaluation for a particular phase and not the complete course."
--"It is usually difficult to ask the right questions and even if you do, you do not know what criteria the person who is responding is using for each item on the questionnaire."

D. Discussion about the "effort to obtain" information

--"Information is not available when decision must be made."
--"Rarely is all this information available in the real world at the time the equipment is selected."

E. Most experts underestimated difficulty

--"This should be easy to do but just isn't."
--"I think I rated this information harder to obtain because I am not satisfied with anything but 'hard' data."
--"I think the Navy doesn't have a readily accessible system to do this--the data are probably there but hard to get."
--"For the most part my ratings are higher on the effort side because of bitter experience at trying to pry these things loose from the fleet and the primes."

F. Experts overestimated difficulty

--"This may not be documented but it's usually easy to find out."

G. Ideas for new work, areas of consideration

--"What is missing or weak are questions addressing linkage between recommendation and adaptation, i.e. <u>who is</u> decision maker?"
--"I do feel that training simulators could have a major impact on ... maintenance training (at all levels)... but, unfortunately the manufacturers of these simulators (and even the research community) have totally failed to exploit the potential capabilities of these systems... I would suggest that the Naval administrators first find out how to more imaginatively use simulators and how to stimulate a new and more instructionally relevant generation of simulators to be built.."

--"I have always believed that a few courses should be offered in the design of simulators... the need to train engineers and others to design simulators is a real need... I would suggest that your study be the beginning of a handbook or textbook, to be published by a major technical publisher... Such a test would be the guts of a course which could be given through an extension division of a state institution. Such a course could run during the summers and be sponsored, i.e., supported spiritually (not financially), by the military training organizations. I readily admit that the number of individuals reading the book and/or taking the course will always be relatively small. Despite this, the need explored in the context of your Delphi study is real and will probably increase over the next 25 years--our productive lifespans."

--"I don't believe the Navy is taking advantage of the technical skills available when they (simulators) are designed. There is absolutely too much inferior workmanship in some of the details. I have pointed this out to a number of people but I never get any kind of feedback. Does the Navy intend to let these people continue to put out consoles that fall apart and electronic boards that will only fit in certain slots?"

H. Justification for changes/choices on earlier questionnaires

Changes

--"My opinions on cost effectiveness, which are more liberal than average, are based on the data (limited data) which are available comparing the _____ with MTUs. These data generally show enormous savings ratios."

--"I have changed my mind. I talked with _____ who teaches and uses the _____ for the hydraulics systems. He has convinced me that they are superior to mock-ups, for instance, the ease of entering system malfunctions, upkeep and space requirements."

--"Marked wrong block first time."

Remained with first choice

--"I insist, it requires extreme effort to do this right."

--"Provisioning is critical."

--"I insist, "hands on" experience is the only way."

--I do not wish to change any of the opinions expressed as they are my own. After 15 years of working with aircraft... and now working and teaching daily with simulators, I feel that some areas of instruction just cannot be simulated adequately."
--"Without further amplification of the questions, I find it difficult for an expert to change his mind merely on the basis that others checked a different block."

I. Skepticism of simulator manufacturers

--"The manufacturers tell one story when selling something and another when they have to repair it or supply parts for it."

J. Difficulty with cost comparisons

--(Simulators) may not be less expensive in the long run."
--I am somewhat rusty when comparing the cost of simulators and cost of operational equipment for each particular subsystem."
--"Development costs (for simulators) are high and are in addition to development costs for the original equipment."
--"Depending on the quality of the training analyses and the specifications derived from them, simulators could be less expensive--or more cost-effective, which you probably should have asked about--then operational gear."
--"I had difficulty with the $200,000 limit."
--"I think you are mistaken to set a limit of 200K per device. Each requirement should be handled on an individual basis."

K. Criticism of O and I Tables

--"Considering the limited nature of O level tasks, simulation is easily applied to all categories of equipment."
--"In this day and age anything along the lines of this inquiry is feasible. Just because something is feasible does not mean it's necessary... each situation of each area of each system must be analyzed and determined on actual facts and this determines what method is best to present the material to be learned."
--"I just don't feel comfortable trying to answer such

abstract questions about these systems, even though I'm familiar with most of the systems. Current state of the art probably makes simulation feasible for all such systems. Properly used such simulators could be more effective than operational equipment."

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